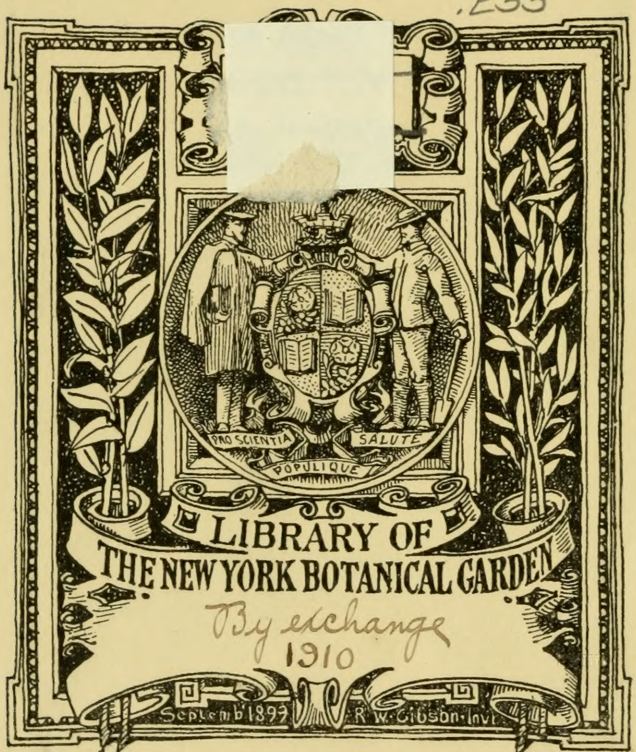
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BOTANICAL SERIES

VOL. III

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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I. INTRODUCTION.

Yellow-Flowered Tobacco (*Nicotiana rustica*, L.), is widely cultivated in India and is found principally in Eastern Bengal and Assam, Bengal, the United Provinces, the Punjab, and also in Kashmir. In some Districts of the Punjab and also in Purnea it is said to be supplanting the cultivated forms of *N. tabacum*, L., while it is the prevailing species in the damper soils of the southern portion of the tobacco-growing District of Rangpur. This species is hardier, requires a shorter time to come to maturity and is said to give a higher yield than *N. tabacum*. So little is known of this tobacco in India that it is stated that no different races of the species exist.[1]

The area occupied by the tobacco crop in India is estimated by Watt at 1,100,000 acres. The total annual value, at £5, or Rs. 75 per acre, is considered by Coventry[2] to exceed five million pounds sterling, which would bring tobacco into the fifth or sixth position of importance among the crops of India.

[1] Watt, *The Commercial Products of India*, 1908, pp. 797 & 798.

[2] Coventry, *Proceedings of the Board of Agriculture in India*, 1906 p. 77.

The first step in the improvement of Indian tobaccos was necessarily the study of the various races at present cultivated in the country. The material for this work was obtained from a large collection of Indian tobaccos growing on the Púsa Farm in 1907. This collection was made in 1905 and our selections were made from the second generation of Púsa-grown plants. All the types, both of *N. tabacum* and also of *N. rustica*, were selected in 1907 and have been grown in pure culture in the Botanical Area at Púsa for the last two seasons.

The objects of the work are threefold :—

1. The study of the varietal characters and the amount of variation in the Indian types of tobacco.

2. The isolation and growth in pure culture of all the constant forms obtained and the determination of the best types in cultivation. By this means seed of definitely described types is now for the first time available for variety trials and also for hybridization work. We have already found that the value, both as regards yield and quality of leaf, of the various types of *N. rustica* varies very considerably. It appears exceedingly likely that by the cultivation of the best of the pure types already isolated, a considerable improvement in the crop would at once result. The quality of the various types is still under investigation and will be dealt with in future papers.

3. The study of the inheritance of characters in tobacco and the production of new and improved races.

The present paper contains an account of the work so far done on *N. rustica* with regard to 1 and 2. The results obtained in the case of *N. tabacum* and also in tobacco breeding will be described in subsequent papers.

Since the publication of Dunal's enumeration of the species of the genus *Nicotiana*[1] in 1852, a monograph on the same subject by Comes[2] has appeared. This author has reduced Dunal's 58 species to 41 and has considerably altered the sections *Tabacum*

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[1] De Candolle, *Prodromus*, XIII, 1, 1852, p 556.

[2] Comes, *Monographie du genre Nicotiana*, Naples, 1899.

and *Rustica*. Comes considers that *N. rustica* has given rise, on account of the very different climatic conditions under which it has been cultivated from time immemorial in the new world, to the following six varieties :—

1. Var. *texana*, Comes. This is said to be a native of Mexico and to be the first variety of tobacco introduced from Florida into Portugal. The *Calcuttya* tobacco, cultivated in India, is said by Comes to belong to this variety.

2. Var. *jamaciensis*, Comes. This variety seems to have been founded on herbarium specimens only and is said to be a native of Jamaica, Guatemala and Mexico. Nothing appears to be known, however, as regards the cultivation of this form for commercial purposes.

3. Var. *asiatica*, Schrank. This variety is grown in Syria, Arabia, Persia and Abyssinia, and is said to be the best snuff tobacco in cultivation.

4. Var. *brasilia*, Schrank. This variety is the one largely cultivated in Europe for the manufacture of snuff.

5. Var. *humilis*, Schrank. This variety also is said to be extensively cultivated for the manufacture of snuff.

6. Var. *scabra*, Comes. A native of South America of no commercial importance on account of its disagreeable odour.

A careful study of the descriptions of these six varieties and of the illustrations in Comes' monograph indicates that these varieties are by no means well marked. Further, when it is remembered that natural cross-fertilization can easily take place between the various races, it is not difficult to understand that the limits of the varieties would quickly be lost.

On attempting to refer the Indian forms to the above varieties, difficulties were at once encountered. The majority of the types in cultivation at Púsa do not resemble any one variety, but possess characters, some of which agree with one of Comes' varieties and the others with one or more of the remaining varieties. Furthermore, the Indian types form a series, and even if broken up into classes, there are intermediate forms which may with equal justice be placed in either of two groups. It appeared

more desirable therefore to arrange the Indian forms in classes, than to attempt to refer them to the six varieties above. Later, it is hoped to obtain the cultivated forms of this species from other countries and to compare them with the indigenous types.

II. THE METHODS EMPLOYED IN RAISING THE EXPERIMENTAL PLANTS.

The cultivation of *N. rustica* in India follows closely that practised in the case of the allied species, *N. tabacum*. In Bihár, high-lying well-manured fields are selected for this crop and the land is kept fallow after the previous *rabi* harvest and continually cultivated. In some districts, hardly any rotation is practised, tobacco following tobacco for several years on the same land. The seeds are sown in raised nurseries, to prevent flooding by rain, after the end of the monsoon and the seedlings, when about 3 inches high, are planted out in the field, about 12 to 18 inches apart each way and rather closer together than in ordinary tobacco. Transplanting is done in the late afternoon, the young plants are watered for a few days and covered, during the heat of the day, with leaves until they are established.

After this, two objects are kept in view : (1) the land is kept free from weeds and continually surface-cultivated with the *khurpi* or hand-hoe ; and (2) the tobacco plants are prevented from wasting their energies in the production of suckers and flowers. When the plants are about 18 inches high, the tops are broken off and a small skewer is inserted at the fracture and pushed a little way down. The ryots believe this has the effect of dwarfing the plant and prevents it throwing out more suckers. Each topped plant bears eight to ten leaves, which constitute the crop. The plants are cut down as a whole in February and cured in the country fashion. The object of the ryot is to grow as large a quantity as possible of coarse, strong tobacco. Quality is not considered, and such operations as priming are not carried out.

The study of the characters of the tobacco plant in the field and their inheritance is beset with special practical difficulties. Much has been said in the literature on the marked variation

produced in tobacco by the soil and the general climatic conditions both on the quality of the crop and also on the form of the plant. It is clear that in order to obtain reliable evidence on the characters of the plant, and also on the inheritance of these characters, one of the first conditions is to prevent any possible contamination of the cultures.

The first difficulty experienced in growing a large number of pure cultures is concerned with the raising of the seedlings. As mentioned above, the ryots grow their seedlings in raised seed beds. This, however, is clearly impracticable in the case of several hundred cultures. In the first place, the seeds of tobacco are so small that they might be carried from one bed to another by wind, earthworms, rain or by careless workmen. In the second place, some of the seeds would not germinate when sown, but would come up during the following years, thereby contaminating the land for subsequent nurseries. The vitality of tobacco seed is well known and in the United States the seed is often kept several years. At Púsa, in 1905, some tobacco was allowed to go to seed in one of the fields, and a certain amount of seed found its way into the soil. Every year stray seedlings have been noticed on this site and also on land at a lower level which receives the surface drainage of the field in question. The practice adopted at Púsa is to raise the seedlings in large boxes and every precaution is taken to collect the earth and leaf mould from places where contamination by stray tobacco seed is impossible. The boxes are made up about six weeks before sowing and kept moist so as to cause any chance seeds to germinate. So far no tobacco seedlings have been found in the boxes prior to sowing. The boxes are sown one at a time and the sower has to wash his hands before sowing another box. After sowing each box it is immediately removed to the shade of trees till the seedlings appear and up to planting time the boxes are enclosed in a wire netting fence to keep off animals and are watched day and night. Precautions are taken during the process of thinning to prevent admixture. The boys who do this work have to wash their hands after finishing each box, as otherwise a few ungerminated seeds

FURROW-IRRIGATION AT PUSA.

might be carried to other cultures. After transplanting, the soil in the boxes is thrown away and the boxes washed. These precautions have proved successful and in no case has any mixture of the cultures been discovered.

The second difficulty in growing the experimental cultures is met with in transplanting. It is the usual custom in Bihár to plant out the seedlings in the afternoon, to immediately water them and to cover the plants with leaves during the hottest part of the day until they are established. Numerous losses result and it is necessary to fill up the vacancies with fresh plants. With many hundreds of experimental cultures it is obvious that even if every care is taken there is a possibility that in a few cases plants from the wrong box might be taken, and mixed cultures obtained. Even if no mixing took place, the replacement of dead plants leads to unevenness in the rows. These transplanting difficulties were successfully overcome by the adoption of a system of furrow irrigation. After the final preparation of the field, furrows about 18 inches wide and 4 inches deep are laid off at the proper distance, so that there will be a furrow between alternate rows of tobacco (see Plate I). These furrows are then filled several times from a distributing channel which runs at right angles to the rows. The water percolates laterally and soon the soil is well moistened between the furrows. Transplanting is now carried on in the soil, moistened by lateral seepage from the trenches, and the young plants are covered with *nim* (*Melia indica*) leaves during the day which are removed at night. No direct watering is necessary at planting, so the formation of a hard lump of soil round the plant resulting from direct watering is avoided. The check due to transplanting by this method is very small and the plants quickly establish themselves. The loss due to transplanting in 1908 at Púsa, a year of exceedingly short moisture, was about 1 in 200. Most of the losses took place where very few seedlings were available and where consequently very small plants had to be used. It was found, however, that these small plants could be efficiently protected by placing over them small perforated earthen saucers which kept off grasshoppers,

and also had the effect of forcing the plants. Any subsequent watering required by the crop is done by filling the trenches.

During the last three years at Púsa our experimental tobaccos have been grown under furrow irrigation with marked success over the methods adopted by the ryots. The advantages of this method of watering by lateral seepage, are largely bound up with the question of tilth. Wherever tobacco is grown, the importance of a well cultivated and well ærated soil has been emphasised, and it has frequently been laid down that this is the first condition for successful tobacco-growing. Badly cultivated and poorly ærated soil always lead to disaster. The surface rooting habit of tobacco and the exceedingly rapid growth of this crop both demand a proper condition of the soil which would be difficult with surface irrigation. Lateral seepage is so slow that the tilth is not destroyed, and it is also the most economical method of supplying moisture as the loss by evaporation is reduced to a minimum.

The system of furrow irrigation described above might with advantage be adopted in general cultivation. The tobacco crop is an exceedingly valuable one in India and great care is taken by the cultivators in raising it. Its welfare in Bihár to a great extent depends on the *rabi* sowing rains, known as the *hathia*, which fall at the end of September and in the early part of October. These showers, however, are precarious and it is not uncommon for the monsoon to come to an end early and to be followed by rainless hot weather in September and October. Under these circumstances a large number of the young transplanted tobacco seedlings die off and others are devoured by grasshoppers and cut worms. Many plants have to be replaced and a very uneven crop is obtained, resulting in loss of maturity at harvest time. It would not be difficult to completely ensure the crop in dry years by furrow irrigation from wells.

III. POLLINATION AND NATURAL CROSS-FERTILIZATION.

Pollination.

The method of pollination in *Nicotiana rustica* has been studied by several observers. Comes[1] considers this species to be self-fertile. Fruwirth,[2] who obtained good setting under nets, states that self-pollination takes place as the flowers open. This is brought about by the bursting of the four long stamens over the already receptive stigma. After the flowers open, the stamens elongate and are lifted still further above the stigma. Fruwirth and Comes consider, however, that cross-pollination is also possible by means of insects. It appeared therefore that the mode of pollination normally occurring in this species, is self-pollination in the bud brought about by the position of the bursting anthers just above the receptive stigma and that cross-fertilization is rare.

While studying the various Indian types of this species at Púsa, it was observed that in type I some of the flowers dropped off after the fading of the corolla and very few capsules naturally set seed. In this row practically no seed was obtained under bag in the ordinary way. On examining the buds it was found in nearly all cases that the styles were much longer than the stamens and often protruded beyond the still closed bud. Type I had therefore long styled flowers, and it was found necessary in this case to artificially self-fertilize the flowers in order to obtain seed under bag.

It now appeared desirable to examine the flowers of the other types of this species. It was found that the anthers always

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[1] Comes, *Rendiconto della Reale Accademia delle Scienze fisiche e matematiche di Napoli*, Feb. 1879.

[2] Fruwirth, *Die Züchtung der landwirtschaftlichen Kulturpflanzen*, Bd. III, 1906, s. 89.

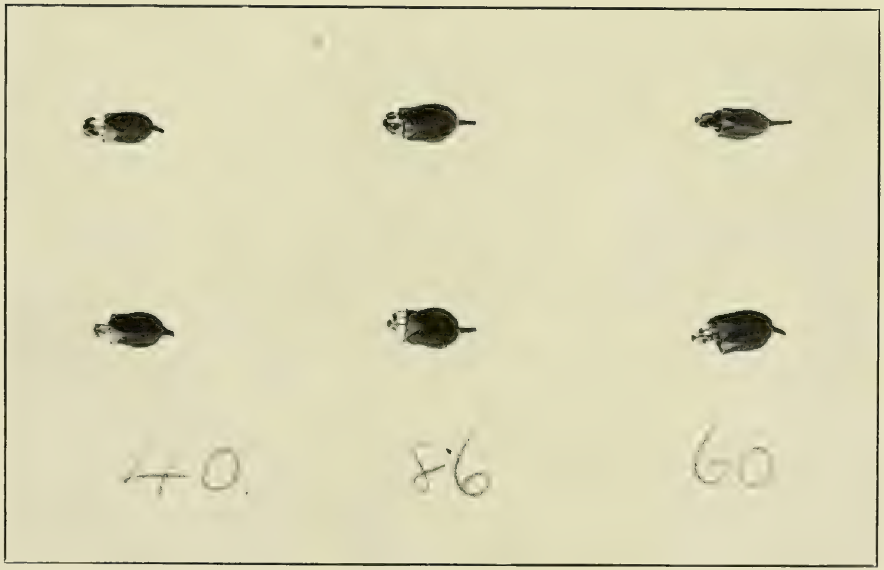
burst in the bud before the corolla opens and that the stigma is receptive at the same time. Homogamy is therefore the rule. The relative position of the stigma and anthers, however, was found to vary considerably between the various types. The general scheme was found to be as follows. The anthers just before the flowers open are either below, opposite or above the stigma, and in all cases they bend towards it. When the pollen is shed, the style elongates and lifts the stigma a little. Then the corolla begins to fade and the anthers recede from the stigma. Every gradation was found in the various types between the condition in which the stamens were above the stigma throughout, rendering cross-pollination practically impossible, and the other extreme case in which all the stamens are so much shorter than the style that self-pollination is only possible by insects or by wind shaking the flowers. Many small bees were noticed visiting the flowers, and some small flies, covered with pollen, were observed inside the corolla tubes. The arrangements for pollination in the various types can be divided into the following three classes (Plate II) :—

Class I.—Stamens much longer than the style.

In this class the style is decidedly shorter than the stamens, so that the four longest stamens bend over the stigma, and in an open flower the stigma is not visible, being always covered by the stamens. In such flowers cross-pollination is almost impossible, and this condition was found in types V and XV.

Class II.— Stamens about the same length as the style.

This class includes the various conditions intermediate between classes I and III, and comprises the majority of the types. The stamens may be a very little longer than the style, so that about half the anther projects above the stigma and the latter in the opened flower is surrounded by the burst anthers, but is not obscured by them as in class I. This condition is found in types XIII and XIV. In other cases the tip of the anther only may project above the stigma and the pollen is deposited round its edge



SHORT. INTERMEDIATE AND LONG-STYLED FLOWERS.

just before the corolla opens, while in the fully-opened flower the empty anthers are clustered round the style just below the stigma. In a few types the anthers may just touch the stigma and the pollen is deposited at its extreme edge or else beneath it. In such cases the anthers are sometimes rather late in bursting and very little pollen is shed before the flower opens.

It is clear that very small differences in the length of the stamens would produce any of these three conditions, and it is not surprising to find that a certain amount of difference can sometimes be found in the flowers of the same plant. For instance, in plants where the anthers normally just touch the stigma, it is usual to find some flowers in which they escape touching it. Thus, in some flowers cross-pollination would be more favoured, in others self-pollination.

Class III.—Style much longer than the stamens.

This extreme condition in which the stigma grows out of the unopened bud into the air and in which self-pollination is exceedingly difficult was only met with in type I. In this type and also in types VI, VII and VIII very few capsules naturally set seed, and it was only possible to obtain seed under bag by artificial selfing.

These observations point to the likelihood of the frequent occurrence, under Indian conditions, of natural cross-fertilization in the field when the types are grown next to next. That natural crossing actually does take place under these circumstances was proved in a large number of cases.

NATURAL CROSS-FERTILIZATION.

During the year 1905 a collection of Indian tobaccos was made by the Púsa Farm, and the sowings were made the same year. A few plants of each sowing were allowed to run to seed without being bagged, and this seed was again sown in the autumn of 1906. In 1907, we selected seed from all the different plants that could be found in these sowings, and the seed from each plant was sown separately by us the same year. Opportunities for natural cross-fertilization at Púsa were therefore possible for two seasons, 1906 and 1907, before we took

over the work. As only few of the plants, however, were allowed to flower in both years, these opportunities were not numerous. Cross-fertilization, although previously possible in the various tracts of India from which the seed was collected, is not likely to be of frequent occurrence on account of the fact that but few plants are allowed to run to seed by the ryots and that the fields of *N. rustica* are very scattered. In 1908, it was found that out of 45 rows of *N. rustica*, each grown from the seed of one plant, 9 were not uniform but contained plants differing from the rest. In 1908, a large number of these aberrant plants were bagged as well as the parent seed plants selected from the uniform rows. The seeds of these plants were again sown separately the same year. In every case the aberrant plants proved to be crosses and gave rise to the most diverse forms (Plate III). In one case infertile plants, with peculiar foliage which may possibly be hybrids between *N. rustica* or *N. tabacum*, were observed (Plate IV). The selected plants from the uniform rows, however, bred true. Natural crossing is therefore frequent in many types of this species, and it will always be necessary in experimental work to obtain seed under bag. No diminution in vigour in the self-fertilized seed obtained under bag has been noticed by us during the past two years. The uniformity of the rows obtained from bagged seed is remarkable. Fruwirth,[1] who grew this species for three years in Germany from selfed seed, did not observe any lack of vigour in the offspring compared with that from free flowering plants. He states :—" Ein Zurückstehen der Pflanzen aus derart gewonnenen Samen gegenüber solchen, welche aus Samen frei abgeblühter Pflanzen erwachsen waren, konnte ich nicht feststellen. Auch die dritte Generation bei ständigem Einschluss war nicht merkbar geschwächt."

The production of self-pollinated seed.

The production of selfed seed under bag in this species offers no particular difficulty. Large waterproof bags are desirable,

[1] Fruwirth l. c.

THE PROGENY OF A SELF-POLLINATED ABERRANT PLANT.

AN EXAMPLE OF NATURAL CROSS-FERTILISATION.

A SECOND EXAMPLE OF NATURAL CROSS-FERTILISATION.

and we have found it best to thin out the main inflorescence very considerably by cutting off the very young buds as well as the opened flowers and capsules before the bag is placed in position. In this way, only buds which would naturally open during the next two days are bagged, and self-pollination rapidly takes place. Bagging should not be left too late in the season as the later flowers on the main inflorescence and most of those on side shoots do not set seed readily. All suckers and side flowering branches are removed at the time of bagging and the whole energy of the plant is utilised in the production of selfed seeds. The bags are removed as soon as all the corollas have faded, and the capsules are allowed to ripen in the air. The bags should on no account be left on too long as this leads to the falling of the capsules. These are counted at the time the bag is removed and indicated by a label which is tied on the stem just below the lowest bagged capsule. Any flower buds which arise above this point, as well as any others on the rest of the plant, are carefully removed from time to time. Unless this is done with great care, the new buds grow rapidly and set seed. The capsules may either be collected as they ripen or else the bag can be replaced when they begin to turn brown. The ripe capsules of this species do not drop off so easily as is the case in some of the races of *N. tabacum*, and this second bagging is therefore not so necessary.

While the above procedure gives satisfactory results in most of the Indian types of this species, it is not successful in the long-styled forms. Practically no seed is obtained under bag with these forms. In such cases the method has to be modified. The unopened buds are bagged and the fully-opened flowers are artificially selfed and the bag replaced. In this way only can good setting be obtained.

The seeds are thoroughly dried in the sun in bags and stored either in bottles or preferably in air-tight cases with a little calcium chloride during the monsoon. They retain their germinating power for several years.

IV. CLASSIFICATION AND DESCRIPTION OF THE TYPES.

Morphological characters.

The study of the characters of this group of tobaccos is not an easy matter. We have to deal with a plant which adapts itself in the most remarkable and intimate manner to the method of cultivation, to the available moisture and to the food materials in the soil, giving rise, according to circumstances, to every gradation of crop from small starved specimens to rank overgrown plants. The types, however, breed true even to the most minute morphological characters. In order to appreciate the differences between the types it is best to study them in normally developed specimens such as are produced when the supply of moisture and manure is carefully regulated. Another difficulty lies in expressing accurately on paper the differences between the various types. The differences are principally of degree only and are largely bound up with the habit of the plant and the characters of the leaves such as the tone of colour and texture. Many of these differences are too subtle to be expressed by an ordinary botanical description, and to appreciate them thoroughly it is necessary to study the plants themselves grown side by side.

(*a*) *Habit.*—The differences in habit of the types are due to the length of the internodes and also depend on the inflorescence, which may be raised well above the leaves or contracted. The height of the plants, of course, varies with the general condition of nutrition. In the 1909 crop, the height of the smallest type was 59 cms., that of the tallest 142 cms. The measurements are taken after the early capsules are formed. The habit is the most distinctive character of the type, but one that is difficult to describe adequately. It is well seen in the photographs.

(*b*) *Leaves.*—The general shape of the leaves of all the types grown is very much the same throughout. They are always petiolate, vary in shape from subcordate to orbicular and are usually slightly asymmetric. The average length of the petiole varies from 5·5 to 9 cms. The average length of the lamina varies from 18·5 to 34 cms. and the ratio length breadth from ·98 to 1·19. These measurements, taken on the 1909 crop, are only of relative value. The margin is generally undulate, but the amount of undulation varies and in some of the types the margin is flat and entire. The apex varies from acute to rounded. The surface of the leaf may be flat or variously puckered, and the texture, which is generally thick and coarse, is much finer in some of the types. The colour is usually dark bluish-green, but lighter green and even yellowish-green leaved types occur. After the habit, the surface, texture and colour of the leaves are the characters of greatest value in distinguishing the races. The angle of insertion of the leaves varies considerably and helps to give each type its characteristic appearance. The leaves of the inflorescence are much smaller than the lower leaves and in the bushy types are merely small editions of these. The ground leaves, as a rule, are much smaller than the rest of those on the lower part of the plant and soon dry up. These were left out of consideration and the measurement made on the third and fourth of the typical leaves. The large lower leaves pass by various stages to the small leaves of the inflorescence.

(*c*) *Inflorescence.*—The inflorescence varies from the open and elongated type by every gradation to very compact and crowded cauliflower-like forms. In the open elongated inflorescences the flowers are often sparsely arranged; in the compact ones the flowers are very closely packed.

(*d*) *Flowers.*—The flowers of this species do not appear to have been studied in any great detail. Considerable differences between the flowers of the various Indian types have been observed both as regards the size and form of the various parts. As regards the size of the flowers, the length with one exception is practically the same in all and only varies from 18 to 20mm. The

diameter, however, varies considerably and three classes can be distinguished :—

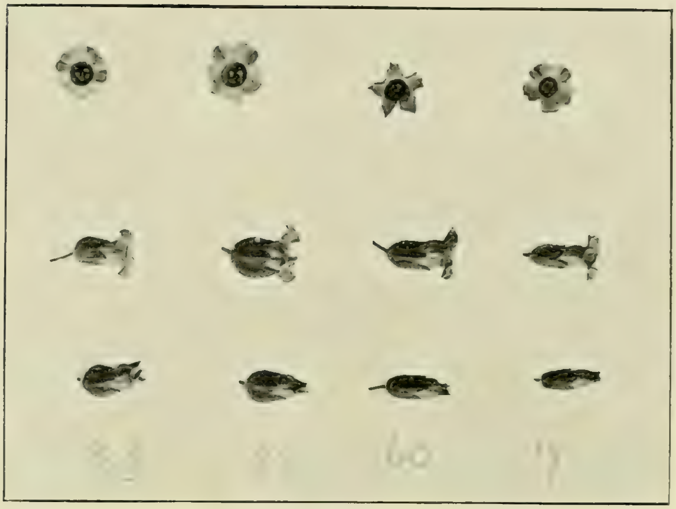
1. Slender flowers in which the maximum diameter of the calyx is 10mm. or less. The buds of these narrow flowers are very pointed.

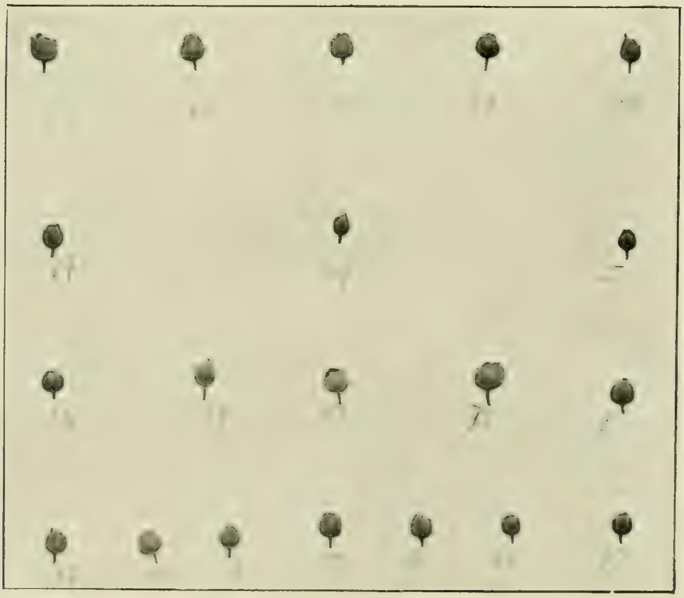
2. Medium flowers in which the diameter varies from 11 to 14mm.

3. Broad flowers in which the diameter is 15mm. or more. In these the calyx is loose and baggy, and the diameter is about 2mm. more than the corolla, and to this is due the peculiar appearance of the flowers of this class.

Calyx.—The relative length of the calyx and corolla varies. The persistent gamosepalous calyx has five teeth, the posterior one of which is always longer than the rest. The remaining four are more or less uneven. The length of the teeth as well as their shape varies. They may be short and obtuse or long and somewhat acute. As a rule, the midrib of the sepals is inconspicuous, but in type I it is well marked as a dark green ridge. In shape the calyx varies from tubular to globular. In the former case the flower has a straight appearance, while in the latter there is a distinct median constriction. In some types the calyx is exceedingly loose and baggy and has a much greater diameter than the corolla.

Corolla.—The general appearance of the limb of the corolla as seen in the front view of the fully-opened flower varies. It may be either quite flat and sometimes also reflexed, in which case the lobes are generally somewhat rounded, or it may never be fully expanded, in which case the lobes may be ovate, very distinct and with the edges curved inwards, or the limb may present a wavy, undulating appearance which has been shortly designated as " crumpled " in the descriptions of the types given below. The outline of the limb varies. The divisions between the petals may be very small, a condition usually found when the limb is flat, or the lobes may be rounded and more strongly marked or the limb may be still more deeply cut when the lobes are more or less pointed. There is an apical point to the petals which is much





FLOWERS AND CAPSULES.

more marked in some types than in others, but it is not visible in the front view in cases where the limb is flat as the margin is generally recurved. In the description of the types this condition is described by the term "apiculæ inconspicuous."

In plate V are represented flowers showing the variations in the structure described above. In No. 33 (type II) the calyx is globular, the teeth short and obtuse, the flower medium in size with a median constriction, and the corolla limb flat and very slightly divided. In No. 83 (type XVIII) the flower is large, the calyx loose and baggy and the corolla limb crumpled. In No. 60 (type I) the flower is medium in size, with no median constriction, the calyx is tubular with long, acute teeth and prominent midrib, while the corolla limb is deeply divided and not fully expanded. No. 19 (type VIII) is an example of a slender flower. The difference in the shape of the buds is well seen.

All gradations between the extreme cases figured in plate V are found among the various types, and the determination of the character of the flower is a matter of some difficulty. The later flowers are seldom really typical and are always much smaller, while many flowers with slight abnormalities in the corolla are found.

Capsule.—The capsules vary considerably in size. Types VI & VII have the smallest capsules (Nos. 49 & 5 on Plate V) and type XVII (No. 75) the largest. The shape may be round as in type XVIII (No. 83), conical as in type V (No. 40), or cylindrical as in type XIII (No. 68). The apex may be rounded, blunt or somewhat pointed and may be more or less umbilicate. As will be seen from the plate, the extent to which the capsule is covered by the persistent calyx varies in the different types. There is a certain amount of variation on this point, though to a much smaller degree, in the capsules of each plant. Often the persistent calyx is split longitudinally by the expanding capsule.

Scheme of Classification.

In arranging the types in a provisional scheme the habit and the nature of the inflorescence have been used as differentiating

characters. The Indian types of *N. rustica* fall naturally into two groups which are easily distinguished in the field: (1) tall plants with open habit and long internodes; (2) short plants with short internodes. Further sub-division is more difficult as the plants in group (1) are all very much alike, while those in group (2) form an almost perfect series. The best division appears to be that based on the nature of the inflorescence which may be open with sparse flowers, somewhat open with flowers crowded, or compact with flowers crowded, giving classes A, B, C. The types within the classes are arranged in order, so that the first type of each class bears the most resemblance to the preceding class. It was generally a matter of some difficulty to decide in which class to place such transitional types. The types within the classes are separated from one another by differences in the arrangement of the leaves, shape, surface and colour of the latter.

I. Tall Plants with long internodes.

Types I, II, III, IV & V.

II. Short Plants with short internodes.

A. Habit open, inflorescence open, flowers not crowded.

(1) Side shoots as long as the main axis, giving the plant a corymbose appearance.

Type VI.

(2) Side shoots not as long as the main axis, giving the plant a pyramidal appearance.

Types VII & VIII.

B. Habit and inflorescence somewhat open but less so than in A, flowers crowded, leaves generally small or medium in size.

Types IX, X, XI, XII, XIII, XIV & XV.

C. Dwarf compact plants. internodes very short, inflorescence compact, flowers crowded, leaves large.

Types XVI, XVII, XVIII, XIX, XX.

Description of the Types.

Group I. Tall plants with long internodes.

Five types (Nos. I to V) are comprised in this group which is well defined by the habit. The height of the plants is due to two factors: (1) the length of the internodes; (2) the open and extended nature of the inflorescence which forms nearly half the plant. Not only are the secondary branches of the inflorescence arranged in an open manner, but the flowers are somewhat distant from one another. Types I to IV are about the same height (135 to 142cms.), but type V, although agreeing in habit with this group, approximates in height somewhat to types VI & VII of the next group.

Types I & V are easily differentiated from the rest, the former by the shape of its leaves and structure of the flower; the latter by its height, small leaves and shape of the inflorescence leaves. Types II, III & IV are much alike, especially III & IV. Type II may be distinguished from the other two by the slenderness of the plant, flatness of the leaves and habit of the inflorescence. Type IV is later, coarser and stouter than type III.

Type I. Plants early; height 135cms. *Leaves* inserted at an angle of about 60°, the lamina afterwards curving towards the ground, subcordate; apex more acute than in the other types of this group; margin very undulate and curving upwards; surface somewhat puckered; colour dark blue-green; average length of petiole 7cms.; average length of lamina 29·5 cms.; ratio length/ breadth = 1·13. *Inflorescence leaves* inserted at an angle of about 45°, elliptical to lanceolate; apex acute; margin undulate; surface flat. *Inflorescence* open; the secondary branches long and slender, almost as long as and running somewhat parallel to the main axis. *Flowers* sparse, medium in size; outline straight, no apparent constriction. *Calyx* somewhat dark green, tubular; midrib of sepals well marked; teeth long and pointed. *Corolla* with very distinct lobes; limb never flat and fully expanded; apiculæ conspicuous. *Capsule* medium in size, a little longer than the calyx, round; apex rounded, scarcely umbilicate.

This type is not adapted for self-fertilization (see p. 9). The stamens are shorter than the style throughout the period of development of the flower, and it is only by shaking or by the agency of wind that self-pollination can be effected. If left to themselves, many of the flowers drop and but few capsules are formed. Artificial pollination and crossing with another type were uniformly successful.

TYPE 1.

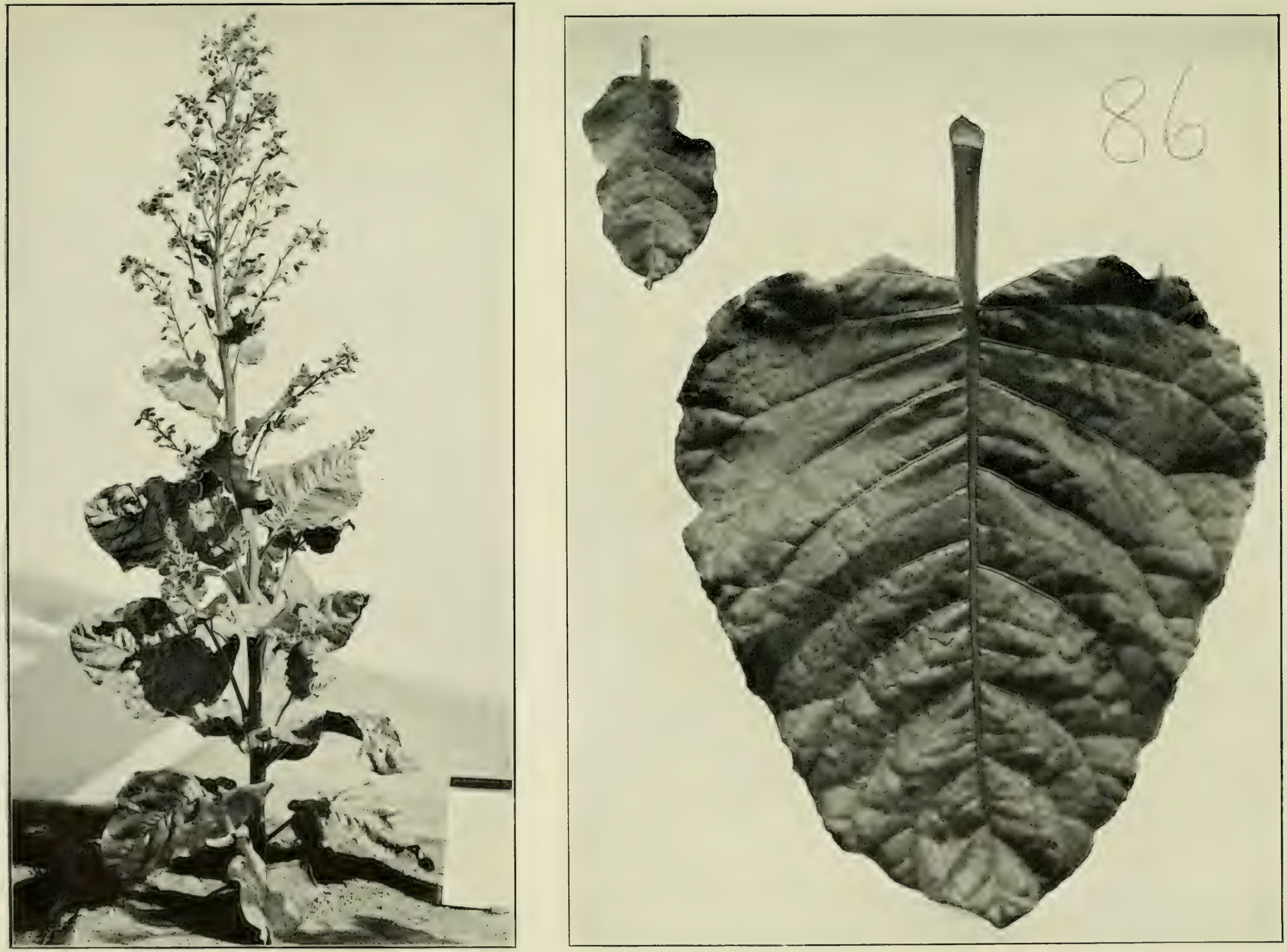
Type II. Plants very early; height 142cms. *Leaves* inserted at an angle of about 60°, subcordate; apex obtuse; margin slightly undulate; surface flat: colour blue-green; average length of petiole 7·5cms.; average length of lamina 25cms.; ratio length / breadth = 1·11. *Inflorescence leaves* inserted at an angle of about 45°, elliptical to lanceolate; apex somewhat obtuse; margin slightly undulate; surface flat. *Inflorescence* open; the secondary branches long and slender, almost as long as, and running somewhat parallel to, the main axis. *Flowers* sparse, medium in size; outline shows a decided constriction. *Calyx* yellowish green, globular, giving the appearance of a constriction in the outline of the flower; midrib of sepals inconspicuous; teeth short and obtuse. *Corolla* with a slightly divided limb which is quite flat and fully expanded; margins of the limb and apiculæ recurved. (Plate V, 33). *Capsule* medium in size, roundly conical, about two-thirds covered by the persistent calyx; apex rounded and umbilicate.

In the flowers of this type cross and self-pollination are both possible. When the anthers burst, the tip of the anther projects slightly above the edge of the stigma, so that the pollen is either deposited on the edge of the stigma or in the tube. When the flower opens and the stamens have shed most of their pollen, the burst anthers are clustered round the style below the stigma. Under bag this type sets very few seeds.

TYPE 2.

Type III. Plants early; height 137cms. *Leaves* inserted at an angle of about 45°, subcordate; apex obtuse; margin undulate; surface somewhat puckered; colour blue-green; average length of petiole 7cms.; average length of lamina 28·5cms.; ratio length/breadth = 1·13. *Inflorescence leaves* inserted at an angle of about 30°, ovate to elliptical; apex acute; margin undulate; surface puckered. *Inflorescence* open; the secondary branches long and slender, but not as long as, nor so parallel to, the main axis as in types I & II. *Flowers* sparse, medium in size; outline shows constriction but less markedly than in type II. *Calyx* somewhat light green, globular, but less so than in type II; teeth short and obtuse. *Corolla* with a slightly divided limb which is quite flat and fully expanded; margins of the limb and apiculæ recurved. *Capsule* medium in size, conical, about half covered by the persistent calyx; apex umbilicate and somewhat pointed.

In this type the mode of pollination is the same as in type II. A slight abnormality was observed in many of the flowers, namely, the stigma projected between the lobes of the corolla in the closed bud.

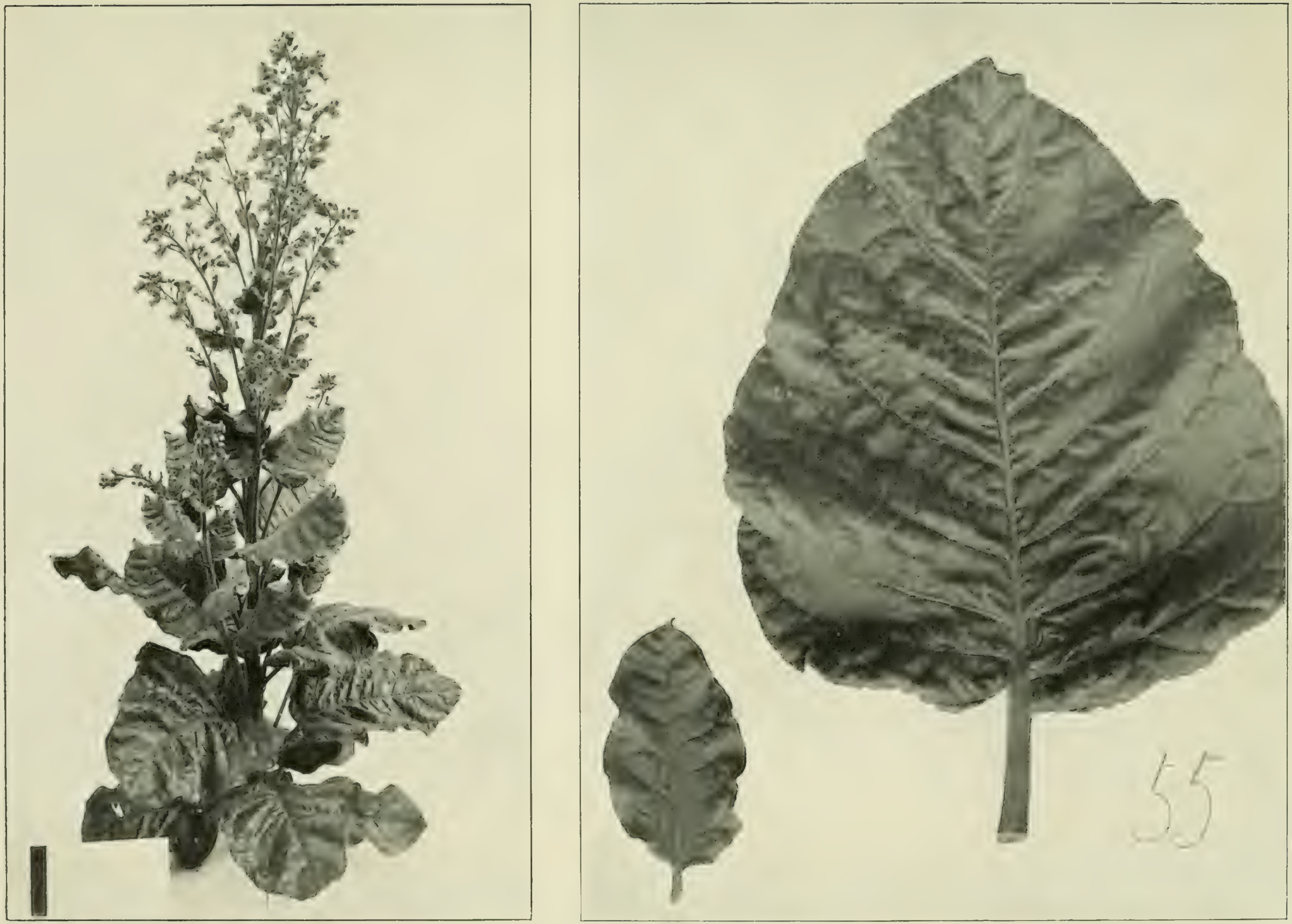


TYPE 3.

Type IV. Plants late ; height 135cms. *Leaves* inserted at an angle of 45°, subcordate ; apex obtuse : margin undulate ; surface more puckered than in type III ; colour blue-green ; average length of petiole 7cms. ; average length of lamina 29·5cms. ; ratio length/breadth = 1·05. *Inflorescence leaves* inserted at an angle of 30°, ovate to elliptical ; apex obtuse to acute ; margin slightly undulate ; surface flat.. *Inflorescence* open ; the secondary branches long and slender, but not so long nor so parallel to the main axis as in types I & II. *Flowers* sparse, medium in size, but larger and coarser than in type III ; no apparent constriction in the outline. *Calyx* loose and baggy ; teeth short and obtuse. *Corolla* with distinct lobes, limb very crumpled ; apiculæ inconspicuous. *Capsule* medium in size, roundly conical, about one-third covered by the persistent calyx ; apex rounded, not markedly umbilicate.

The plants of this type are much stouter and coarser looking than those of the other types in this group.

In this type the anthers surround the stigma and both self- and cross-pollination are possible. Good setting is obtained under bag.



TYPE 4.

Type V. Plants early; height 107cms. *Leaves* inserted at an angle of 60°; subcordate; apex obtuse; margin undulate; surface somewhat puckered; colour blue-green; average length of petiole 7cms.; average length of lamina 24·5cms.; ratio length/breadth = 1·09. *Inflorescence leaves* inserted at an angle of 45°, subcordate to ovate; apex obtuse; margin very slightly undulate: surface flat. *Inflorescence* open: secondary branches shorter than the main axis and not parallel to it. *Flowers* somewhat sparse, small in size: outline shows a decided constriction. Calyx somewhat globular; midrib of sepals fairly prominent; teeth somewhat acute. *Corolla* with distinctly divided limb, which is quite flat and fully expanded; apiculæ well marked. *Capsule* medium in size, conical, about two-thirds covered by the persistent calyx: apex not umbilicate.

Type V is adapted for self-pollination. When the flower opens, the anthers are well above the stigma and completely cover it, making cross-pollination almost impossible (see Plate II, No. 40). Although undoubtedly belonging to group I, this type is more dwarfed than the other members of this group and forms transition between this and the next group.

TYPE 5.

GROUP II. SHORT PLANTS WITH SHORT INTERNODES.

This group includes the fifteen remaining types. The plants are all shorter than in group I and have shorter internodes. Although the different types included in this group vary considerably among themselves, nevertheless, in the field, the difference in habit between the plants of group I and those of group II is most marked. This group is sub-divided into three classes A, B and C according to the character of the inflorescence.

A. Habit open, inflorescence open, flowers not crowded. This class contains three types, VI, VII, VIII. The plants, though shorter than those in group I, still have a somewhat open habit with a moderate length of internode.

(1) Sideshoots as long as the main axis-giving the plant a corymbose appearance.

Type VI.

(2) Sideshoots not as long as the main axis-giving the plants a pyramidal appearance.

Types VII & VIII.

Both VII & VIII are small-leaved forms. They are differentiated partly by the habit. The sideshoots in type VIII are more spreading than in VII, and this difference in appearance is intensified by the difference in the angle of insertion of the leaves. Both these differences tend to disappear later if the plant is allowed to become overgrown and when the leaves lose some of their turgidity. There are also small differences in the individual characters of the lower and inflorescence leaves.

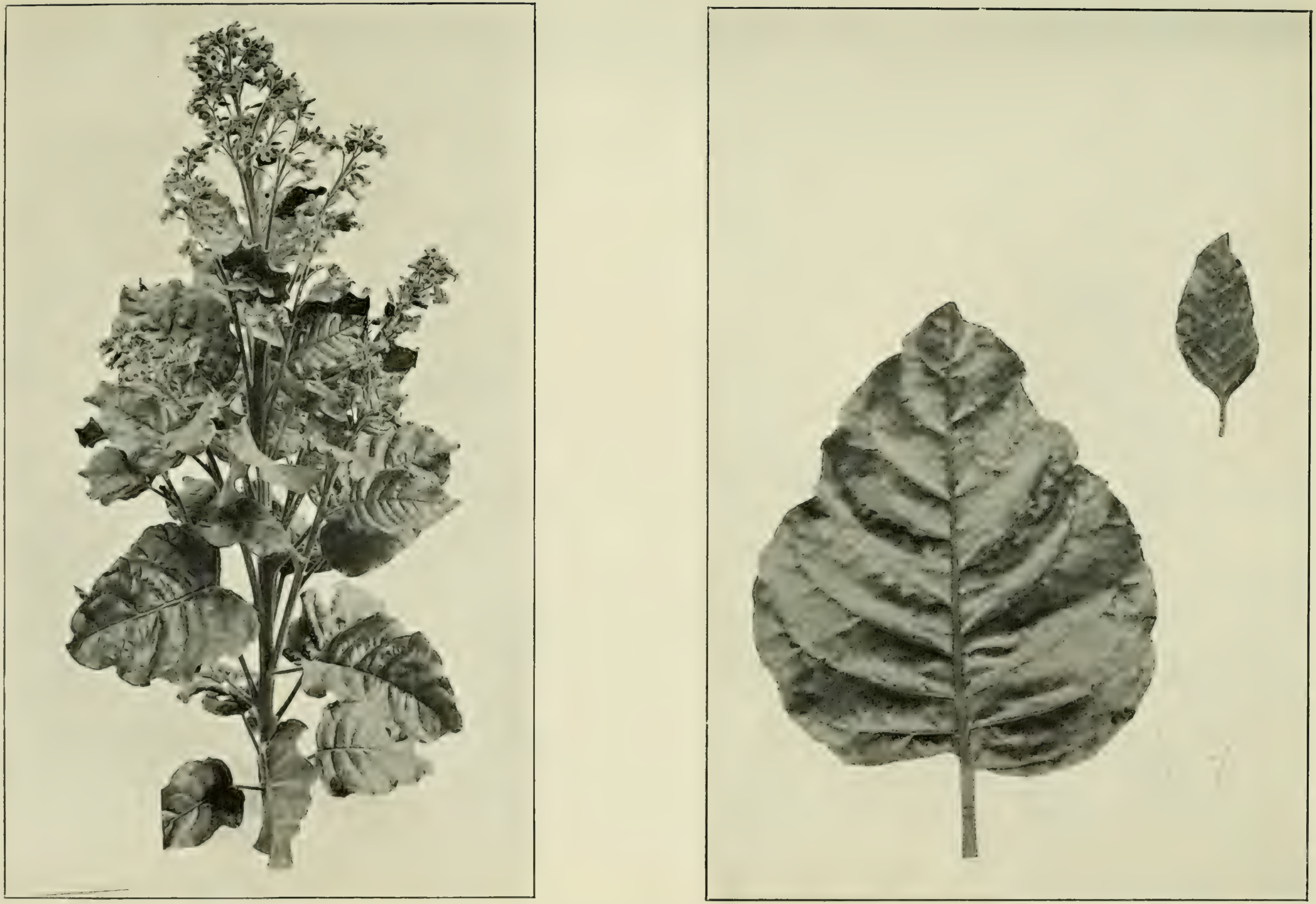
Type VI. Plants very early; height 91cms. *Leaves* inserted at an angle of 60 to 90°, later drooping towards the ground, subcordate; apex obtuse; margin undulate and curved upwards; surface flat and somewhat glossy; colour somewhat light green with comparatively fine texture; average length of petiole 8cms.; average length of lamina 25·5cms; ratio length/breadth = 1·08. *Inflorescence leaves* inserted at an angle of more than 60°, narrowly elliptical; apex obtuse; margin entire; surface flat. *Flowers* sparse, slender. *Calyx* somewhat globular; teeth somewhat acute. *Corolla* with slightly divided lobes; limb flat and fully expanded; apiculæ not very well marked. *Capsule* small, conical, almost covered by the persistent calyx; apex pointed, umbilicate.

This type is not well adapted for self-pollination. The stamens, when shedding their pollen, are shorter than the style, so that the tip either just touches the underside of the stigma or in some cases does not reach it at all. Artificial self-pollination is necessary to obtain pure seed. It will be seen that this type bears a general resemblance to type I in many points.

TYPE 6.

Type VII. Plants early ; height 99cms. *Leaves* inserted at an angle of 45 to 60°; subcordate ; apex obtuse ; margin undulate ; surface puckered ; colour blue-green ; average length of petiole 7cms. ; average length of lamina 18·5cms. ; ratio length/breadth = 1·12. *Inflorescence leaves* inserted at an angle of 30°, elliptical ; apex somewhat acute ; margin undulate ; surface flat. *Inflorescence* open ; secondary branches and sideshoots not as long as the main axis. *Flowers* sparse, slender, longer than in any other type ; outline straight, no apparent constriction. *Calyx* tubular ; teeth somewhat long and acute. *Corolla* with a slightly divided limb which is flat and fully expanded ; apiculæ inconspicuous. *Capsule* small, conical, entirely covered by the persistent calyx ; apex blunt and slightly umbilicate.

In this type both self- and cross-pollination are possible. The stamens are about the same length as the style, the tips of the stamens just projecting above the stigma when the anthers are shedding their pollen. The burst and empty anthers then cluster round the style underneath the stigma.



TYPE 7.

Type VIII. Plants early; height 82cms. *Leaves* inserted at an angle of more than 60°, subcordate; apex somewhat rounded; margin slightly undulate; surface slightly puckered; colour blue-green; average length of petiole 8cms.; average length of lamina 20cms.; ratio length/breadth 1·05. *Inflorescence leaves* inserted at an angle of 60°, broadly elliptical; apex somewhat acute; margin entire; surface flat. *Inflorescence* open; secondary branches and sideshoots not as long as the main axis. *Flowers* sparse, slender. *Calyx* tubular; midrib of the sepals fairly prominent; teeth somewhat long and acute. *Corolla* with very distinct lobes; limb never flat and fully expanded; apiculæ conspicuous. *Capsule* small, cylindrical, about two-thirds covered by the persistent calyx; apex blunt and umbilicate.

Pollination in this type takes place in the same manner as in type VII. In types VI, VII & VIII very few flowers set seeds when protected by bags and it was necessary to resort to artificial self-pollination.

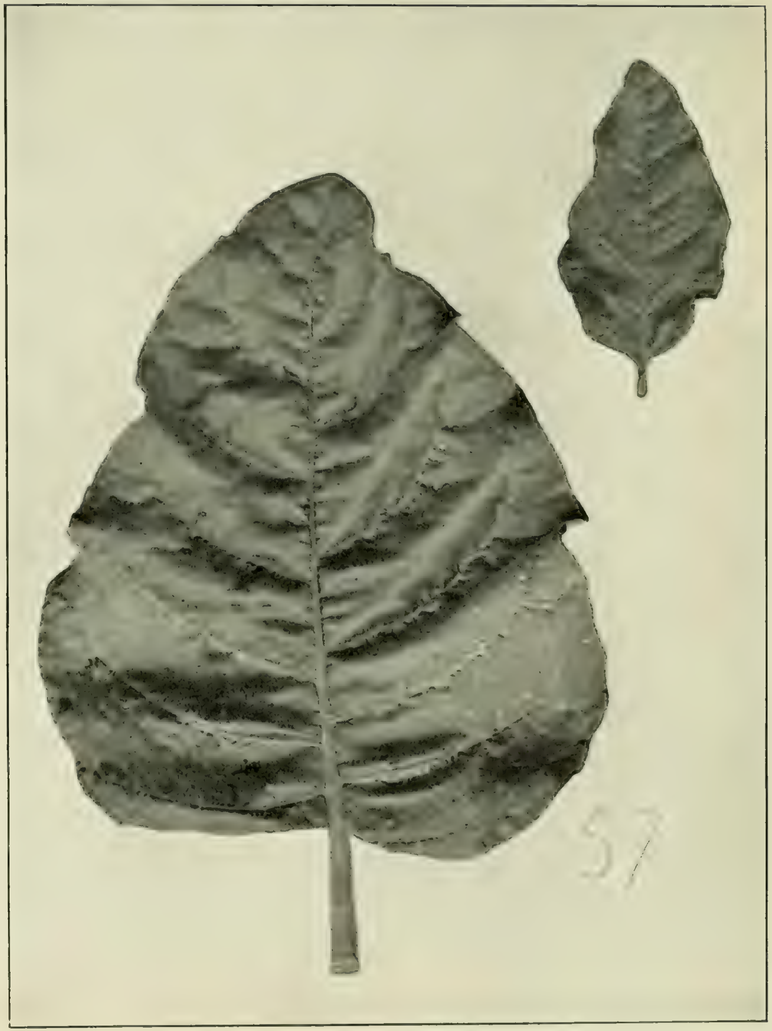
TYPE 8.

B. Habit and inflorescence somewhat open but less so than in class A, flowers crowded, leaves generally small or medium in size. This class contains seven types (IX to XV) and forms a series between plants with the habit of the last class and the compact dwarf plants of class C. There is a considerable variation both in the height (59cms. to 82cms.) and in the general appearance. Although the inflorescence is still somewhat open in character, the flowers on the individual branches are crowded and in most members of this class there is a distinct tendency towards the formation of a compact, crowded central portion of the inflorescence.

Type IX is a transition form between class A and this class. The inflorescence is fairly open. Types XI & XII are very much alike and only differ in small details. Type XII is less robust and shorter than XI and has smaller, thinner leaves. Type X is characterised by its bushy appearance and the light colour and flat surface of its somewhat small leaves. It is intermediate in habit between types IX & XI. Types XIII, XIV & XV are small-leaved forms. Type XIV is easily distinguished by its dwarf habit and by the horizontal arrangement of its leaves. Type XV is exceedingly bushy and the leaves appear more conspicuous than the inflorescence. Type XIII is in some respects a larger edition of type XIV.

Type IX. Plants very bushy and bear a large number of small leaves; height 88cms. *Leaves* inserted at an angle of nearly 90°, subcordate; apex obtuse to rounded; margin slightly undulate; surface almost flat; colour blue-green; average length of petiole 6·5cms.; average length of lamina 24cms.; ratio length/breadth 1·09. *Inflorescence leaves* inserted at an angle of about 90°, ovate to elliptical, there is a gradual transition in shape between the inflorescence leaves in this type; apex obtuse; margin slightly undulate; surface flat. *Inflorescence* fairly open; secondary branches and sideshoots spreading and not as long as the main axis. *Flowers* somewhat crowded, large. *Calyx* loose and baggy; teeth short and obtuse. *Corolla* with a slightly divided, flat limb; apiculæ inconspicuous. *Capsule* medium in size, somewhat rounded, almost covered by the persistent calyx; apex blunt, umbilicate.

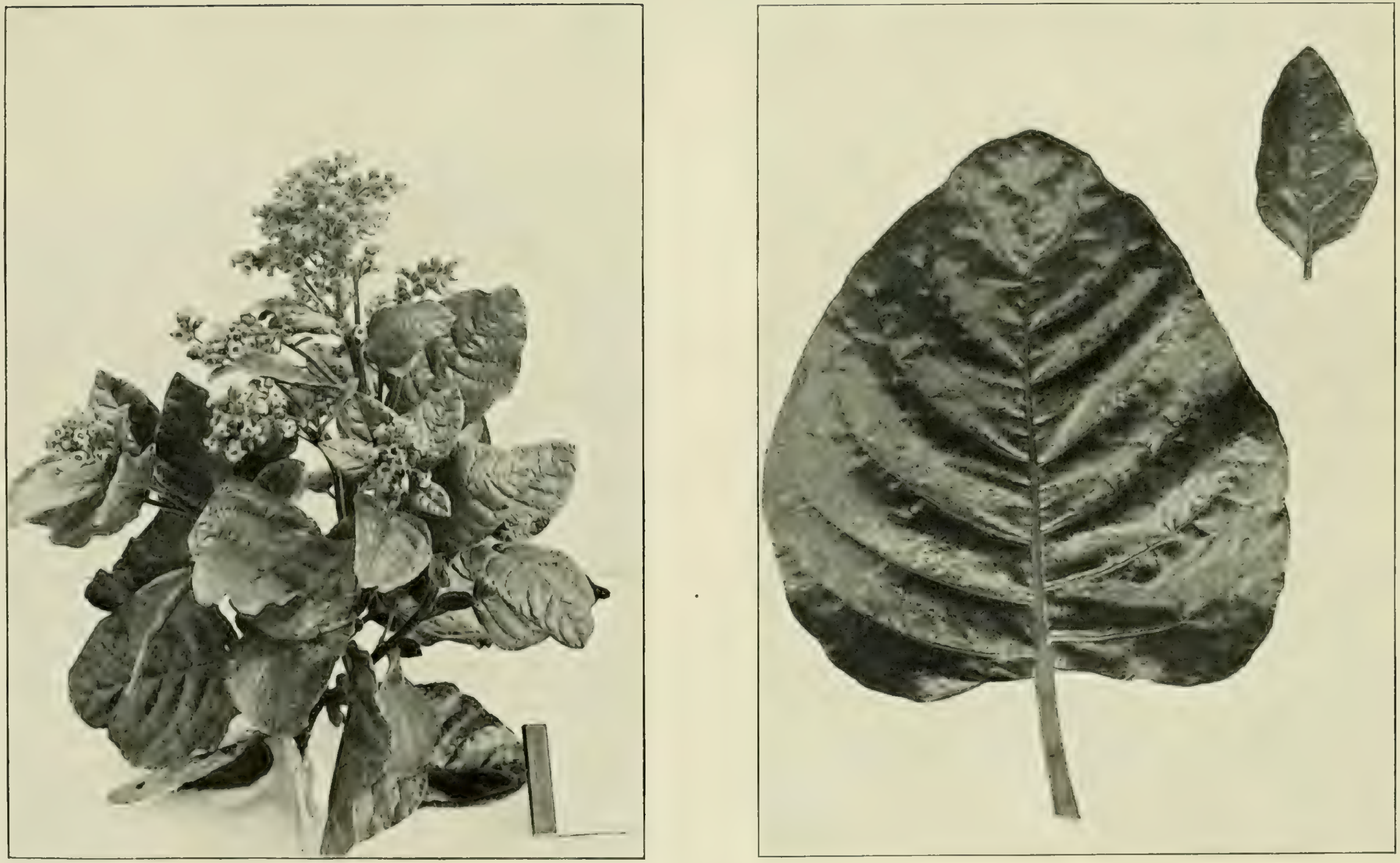
Cross- and self-pollination are both possible in this type. The stamens are approximately equal in length to the style, the tips of the anthers just projecting above the stigma when the pollen is being shed.



TYPE 9.

Type X. Plants bushy owing to the occurrence of larger leaves high up the stem and to the number of leaves, early ; height 70cms. *Leaves* inserted at an angle of nearly 90°, subcordate ; apex rounded ; margin entire ; surface flat ; colour somewhat light green ; average length of petiole 8 cms. ; average length of lamina 22·5 cms. ; ratio length/breadth 1·07. *Inflorescence leaves* inserted at an angle of about 60°, elliptical ; apex obtuse ; margin entire ; surface flat. *Inflorescence* somewhat open ; sideshoots stout and spreading, not as long as the main axis. *Flowers* crowded, small. *Calyx* slightly globular ; teeth short and obtuse. *Corolla* with very distinct lobes ; limb not fully expanded or flat ; apiculæ well marked. *Capsule* small, conical, very long, more than two-thirds covered by the persistent calyx ; apex blunt and umbilicate.

Cross and self-pollination are both possible in this type as the stamens are approximately equal in length to the style. The leaves are thin and of comparatively fine texture.



TYPE 10.

Type XI. Plants early but later than in type XII ; height 81cms. This type differs from types IX and XII in having the inflorescence raised well above the leaves ; height 71cms. *Leaves* inserted at an angle of 60° or more, subcordate ; apex obtuse to rounded ; margin slightly undulate ; surface almost flat ; colour dark blue-green ; average length of petiole 7 cms. ; average length of lamina 26cms. ; ratio length/breadth 1·17. *Inflorescence leaves* inserted at an angle of 60°, elliptical ; apex obtuse ; margin very slightly undulate ; surface flat. *Inflorescence* raised and somewhat open ; secondary branches not as long as the main axis. *Flowers* crowded, medium in size. *Calyx* very slightly globular ; teeth short and obtuse. *Corolla* with distinct lobes ; limb never flat or fully expanded ; apiculæ well marked. *Capsule* medium in size, conical, half covered by the persistent calyx ; apex somewhat pointed and umbilicate.

Cross- and self-pollination are both possible in this type as the stamens and style are approximately equal in length.


TYPE 11.

Type XII. Resembles type XI very closely, but is earlier, shorter and less robust, the leaves are smaller and thinner, the limb of the corolla is flat and fully expanded and the capsule less conical and with a blunter apex; height 71cms.; average length of petiole 6cms.; average length of lamina 25cms.; ratio length/breadth 1·09.

TYPE 12.

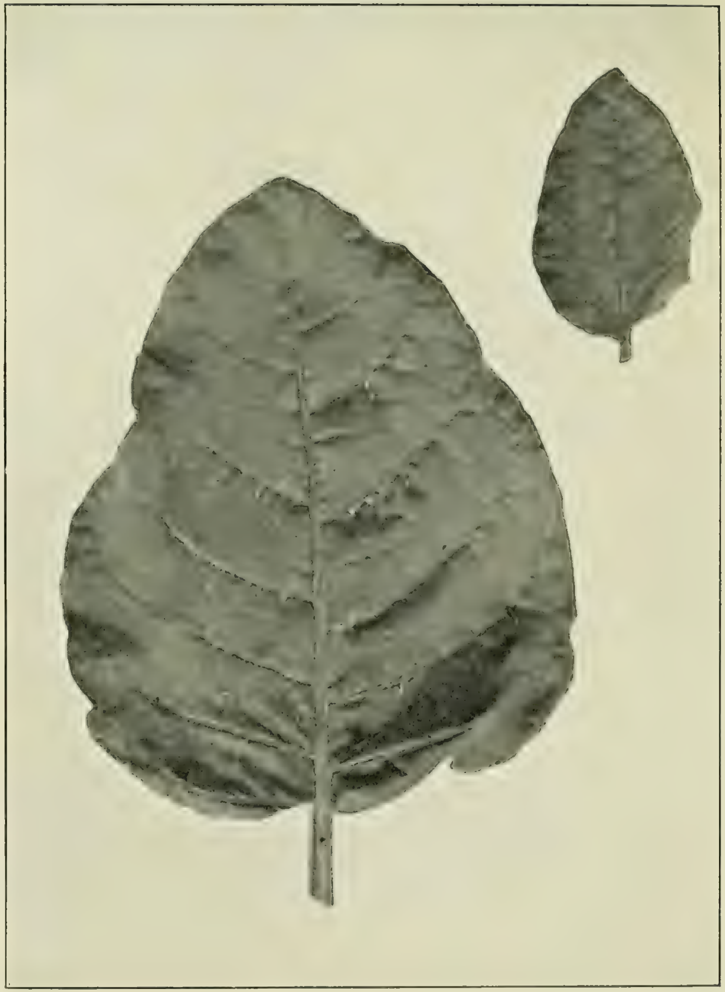
Type XIII. Plants early, bushy, bearing a large number of small leaves up the whole stem; height 79cms. *Leaves* inserted at an angle of about 60° or less, subcordate; apex rounded; margin very undulate; surface very puckered; colour very dark blue-green; average length of petiole 8cms.; average length of lamina 20·5cms.; ratio length/breadth ·99. *Inflorescence leaves* inserted at an angle of 45°, broadly elliptical; apex obtuse to rounded; margin slightly undulate; surface slightly puckered. *Inflorescence* somewhat open; secondary branches and sideshoots not as long as the main axis. *Flowers* crowded, slender. *Calyx* tubular; teeth somewhat acute and leafy. *Corolla* with a slightly divided limb, somewhat crumpled; apiculæ not conspicuous. *Capsule* small, cylindrical, about two-thirds covered by the persistent calyx; apex blunt and umbilicate.

In this type self-pollination is predominant. The stamens are slightly longer than the style, so that when the pollen is being shed, the anthers are above the stigma for at least half their length, and when empty they cluster round the edge.

TYPE 13.

Type XIV. Plants early, very short; height 59cms. *Leaves* inserted at an angle of 90° ; subcordate ; apex obtuse ; margin very slightly undulate ; surface flat ; colour blue-green ; average length of petiole 5·5cms. ; average length of lamina 21·5cms. ; ratio length/breadth 1·17. *Inflorescence leaves* inserted at an angle of 90°, elliptical ; apex obtuse ; margin entire ; surface flat. *Flowers* slender, crowded. *Calyx* tubular ; teeth short and obtuse. *Corolla* with very distinct lobes ; limb never fully expanded or flat ; apiculæ well marked. *Capsule* small, cylindrical, about two-thirds covered by the persistent calyx ; apex blunt and umbilicate.

Pollination takes place in this type in the same manner as in type XIII.



TYPE 14.

Type XV. Plants late, very bushy partly owing to the comparatively large size of the inflorescence leaves; height 82 cms. *Leaves* inserted at an angle of 45°, subcordate; apex obtuse to rounded; margin very undulate; surface very puckered; colour dark blue-green; average length of petiole 9cms.; average length of lamina 21cms.; ratio length/breadth ·98. *Inflorescence leaves* inserted at an angle of 30° to 45° and resemble the lower leaves in every way but are smaller. *Inflorescence* neither very compact nor very open; sideshoots long but not as long as the main axis. *Flowers* crowded, slender. *Calyx* tubular; teeth obtuse. *Corolla* with a very slightly divided limb which is flat; apiculæ inconspicuous. *Capsule* small, rounded, almost covered by the persistent calyx; apex blunt and not umbilicate.

In this type self-pollination is predominant, the stamens are raised well above the stigma and completely cover it when the flower opens and the pollen is being shed.

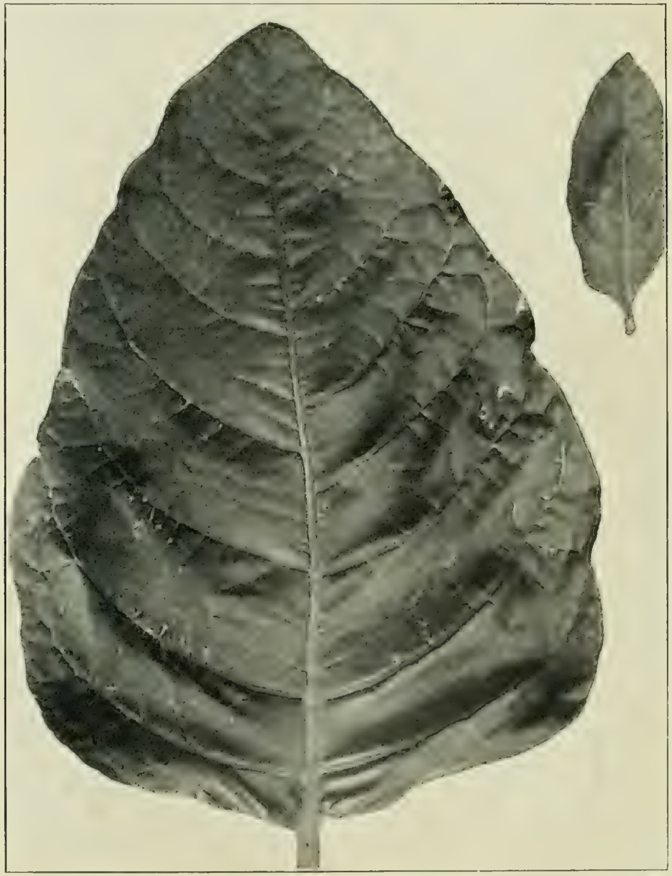
TYPE 15.

C. Dwarf compact plants, internodes very short, inflorescence compact, flowers crowded, leaves large. The chief characteristic of this group is the condensed form of the inflorescence. The compact central mass of flowers is sunk among the leaves, and although the inflorcesence grows out later when the capsules form, most of the flowers open before this. The flowers are so closely packed that the operation of bagging is most difficult.

The five types contained in this class are easily differentiated. Type XVI is a transition form between classes B and C and might, with almost equal justice, be placed in either class. It is easily distinguished from the other members of this group by the colour, shape and surface of the leaves. Types XVII & XVIII are very vigorous forms with much puckered leaves. They are best differentiated by the shape of the leaves, those in type XVIII being shorter and rounder. The orbicular shape of the leaves in type XX is the best diagnostic character of this form.

Type XVI. Plants late; height 81cms. *Leaves* inserted at an anlge of nearly 90° standing out horizontally from the stem subcordate; apex obtuse; margin flat; surface flat; colour light yellowish-green; average length of petiole 7cms.; average length of lamina 32cms.; ratio length/breadth 1·19. *Inflorescence leaves* inserted at an angle of 45°, elliptical; apex obtuse; margin entire; surface flat. *Inflorescence* opener than in the other members of this group. *Flowers* crowded, large. *Calyx* loose and baggy; teeth short and obtuse. *Corolla* with a very slightly divided limb which is flat and fully expanded; apiculæ well marked. *Capsule* medium in size, round, almost covered by the persistent calyx; apex blunt and umbilicate.

In this type both cross and self-pollination are possible, the stamens being approximately equal in length to the style.



TYPE 16.

Type XVII. Plants very late; height 63cms. *Leaves* inserted at an angle of 45 to 60°, subcordate, almost ovate; apex rounded; margin very undulate; surface very puckered; colour somewhat light green; average length of petiole 9cms.; average length of lamina 34cms.; ratio length/breadth 1·05. *Inflorescence leaves* inserted at an angle of about 60°, elliptical; apex rounded; margin very undulate; surface very puckered. *Flowers* crowded, large. *Calyx* loose and baggy; teeth short and obtuse. *Corolla* with a very slightly divided limb, which is crumpled; apiculæ inconspicuous. *Capsule* large, somewhat conical, two-thirds covered by the persistent calyx; apex rounded and umbilicate.

This type is adapted both for cross- and self-pollination, the stamens being approximately equal in length to the style.

TYPE 17.

Type XVIII. Plants late ; height 72cms. *Leaves* inserted at an angle of 45 to 60°, somewhat orbicular ; apex obtuse to rounded ; margin very undulate ; surface very puckered ; colour dark blue-green ; average length of petiole 9cms. ; average length of lamina 28cms. ; ratio length/breadth ·97. *Inflorescence leaves* inserted at an angle of 45°, ovate or very broadly elliptical ; apex obtuse or rounded ; margin very undulate ; surface very puckered. *Flowers* crowded, large. *Calyx* tubular and loose ; teeth short and obtuse. *Corolla* with a slightly divided limb, which is flat and fully expanded ; apiculæ inconspicuous. *Capsule* large, round, almost covered by the persistent calyx ; apex blunt and umbilicate.

In this type both cross- and self-pollination are possible, the stamens being approximately equal in length to the style. This is a vigorous, very large-leaved type and is very like type XVII, but the leaves are shorter, more orbicular, darker green and thicker.

TYPE 18.

Type XIX. Plants early ; height 63cms. *Leaves* inserted at an angle of nearly 90°, subcordate ; apex obtuse ; margin very slightly undulate ; surface somewhat flat ; colour blue-green ; average length of petiole 8cms. ; average length of lamina 2·55cms. ; ratio length/breadth 1·08. *Inflorescence leaves* inserted at an angle of about 60°, elliptical ; apex somewhat acute ; margin entire ; surface flat. *Flowers* crowded, medium in size. *Calyx* somewhat globular ; teeth short and obtuse. *Corolla* with a very slightly divided limb which is flat and fully expanded ; apiculæ inconspicuous. *Capsule* small to medium in size, not quite round, almost covered by the persistent calyx ; apex blunt and umbilicate.

In this type self-pollination is somewhat favoured. The stamens are slightly longer than the style, the tips of the anthers projecting above the edge of the stigma when the pollen is being shed.

TYPE 19.

Type XX. Plants late; height 64cms. *Leaves* inserted at an angle of about 45°, almost orbicular; apex rounded; margin very slightly undulate; surface slightly puckered; colour dark blue-green; average length of petiole 7cms.; average length of lamina 25·5cms.; ratio length/breadth ·93. *Inflorescence leaves* inserted at an angle of 30 to 45°, very broadly ovate; apex obtuse to rounded; surface flat; margin entire. *Flowers* crowded, large. *Calyx* tubular and loose *Corolla* with a slightly divided limb which is flat and fully expanded; apiculæ inconspicuous. *Capsule* medium in size, round, almost covered by the very leafy calyx; apex blunt and umbilicate.

Cross- and self-pollination are both possible in this type, the stamens being approximately equal in length to the style.

AGRICULTURAL RESEARCH
INSTITUTE, PUSA;
July 5th, 1909.

TYPE 20.

PUBLICATIONS OF THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA.

[To be had from Messrs. THACKER, SPINK & CO., Calcutta.]

Annual Report of the Imperial Department of Agriculture in India for the year 1904-05. Price, As. 12 or 1*s*. 2*d*.

Report of the Imperial Department of Agriculture in India for the years 1905-06 and 1906-07. Price, As. 6 or 7*d*.

Proceedings of the Board of Agriculture in India, held at Pusa on the 6th January 1905 and following days (with Appendices). Price, As. 8 or 9*d*.

Proceedings of the Board of Agriculture in India, held at Pusa on the 15th January 1906 and following days (with Appendices). Price, As. 12 or 1*s*. 2*d*.

Proceedings of the Board of Agriculture in India, held at Cawnpur on the 18th February 1907 and following days (with Appendices). Price, Re. 1-2 or 1*s*. 6*d*.

Proceedings of the Board of Agriculture in India, held at Pusa on the 17th February 1908 and following days (with Appendices). Price, As. 8 or 9*d*.

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BY

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I. INTRODUCTION.

Ordinary tobacco (*Nicotiana tabacum*, L.) is grown all over India and is apparently the only species cultivated in the Peninsula. In this, as in other countries, it forms the most important source of the tobacco of commerce.

In perhaps no other cultivated crop is the question of quality so important as in tobacco. The general opinion seems to be that with the exception of some of the crop grown for cigar-fillers in Madras, the quality of Indian tobacco is not high. Whether this is due to the varieties grown, to the methods of cultivation, to climate, soil and moisture conditions, to the curing or to a combination of these causes is not known with precision. Several attempts have been made in the past to improve the quality of Indian tobacco by the introduction of American and Sumatra varieties and by the employment of American curers, but up to the present no results have been obtained. This want of success seems to have been largely due to the failure on the part of the investigators to realise that the first condition of success in improving this or any other crop is a thorough study

in the first place of all the various aspects of tobacco-growing and manufacture in India.

The first step in the improvement of Indian tobaccos is necessarily the study of the various types at present cultivated in the country. The material for this work was obtained from a large growing collection of Indian tobaccos on the Púsa Farm in 1907. This collection was made in 1905 and our selections were taken from the second generation of Púsa grown plants. All the types both of *N. tabacum* and *N. rustica* were selected in 1907 and have been grown in pure culture in the Botanical area at Púsa for the last two seasons.

The objects of the work in progress at Púsa on Indian tobaccos are as follows :—

1. The study of the varietal characters and the amount of variation in the Indian types of tobacco.

2. The isolation and growth in pure culture of all the constant forms obtained and the determination of the best types in cultivation. By this means seed of definitely described types is now for the first time available for variety trials and also for hybridization work.

3. The introduction, acclimatisation and testing of tobaccos from other parts of the world.

4. The study of the inheritance of characters in tobacco and the production of new and improved types.

The present paper contains an account of the work so far done on *Nicotiana tabacum* with regard to (1) and (2). The stability of the type of tobacco, when introduced into new localities, has been dealt with and also the important results which follow from natural cross-fertilization in the field.

The methods of raising the experimental plants in the case of this species follow closely those already described in the case of *Nicotiana rustica*.[1] The seedlings of this species grow more slowly, are less robust and are established with greater difficulty than those of the yellow-flowered tobaccos.

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[1] Howard and Howard, *Memoirs of the Department of Agriculture in India* (*Botanical Series*), Vol. III, No. 1, 1909.

II. THE STABILITY OF THE TYPE.

"Improvements in methods of culture, curing and fermentation have resulted in the production of tobacco having an increased value, but the most important factor in the development of more valuable tobaccos has been the production of improved varieties by seed selection and breeding. The production of these improved varieties adapted to local soil and climatic conditions has made possible the rapid development of the industry and enabled the United States in a comparatively short time to rank as the foremost tobacco-producing country in the world." (A. D. Shamel and W. W. Cobey, *Tobacco breeding*, Bulletin No. 96, Bureau of Plant Industry, United States Department of Agriculture, 1907, p. 8.)

Perhaps, no other factor in the production of high grade tobacco is so important as uniformity in the crop both as regards growth, and also as regards the type of plant grown. Unless the crop ripens uniformly, the difficulties of harvesting and curing are increased while a crop made up of several types of plant, differing in the size, venation, shape and texture of the leaves, increases the cost of sorting out the various grades for market. The maintenance of the uniformity of any desirable type of tobacco is therefore a matter of prime importance.

While there is agreement on the question of the importance and desirability of maintaining the type, nevertheless there is a general idea in much of the literature on this crop, that the uniformity of the type is easily disturbed by the introduction of any particular kind into a new locality. The use of immature seed, the application of heavy dressings of farmyard manure and commercial fertilizers and a change of soil and climatic conditions, particularly the taking of tobacco seed from southern

or tropical conditions, to the north, are considered by Shamel and Cobey[1] to be some of the causes of variation in the tobacco plant. Killebrew and Myrick[2] consider that soil and climate are two causes constantly in operation in increasing the number or in modifying the character of existing varieties. Lock[3] states: "As the Havanna tobaccos command the highest prices, the cultivator nearly everywhere attempts to introduce and cultivate them. There is no great difficulty in raising plants of these varieties, but they speedily degenerate and form new varieties, if the climatic conditions, etc., are not favourable."

The growth of the collection of Indian tobaccos at Púsa in 1905 afforded us an admirable opportunity of studying the effect of a new locality on the various forms and also the effect of soil and manuring. If the types of tobacco easily change, some alteration should be manifest after four years in the case of forms collected from such widely different localities as Burma, Assam, Madras and the Punjab. If, as is sometimes thought, introduced tobaccos gradually assume the form of those ordinarily cultivated in the district, the process should by this time have manifested itself at Púsa. Observations on the various types and photographs of actual plants for several years have, on the other hand, clearly demonstrated the remarkable uniformity of the types from year to year even to fine shades of colour and small differences in the morphology of the leaves and flowers and in the earliness and general habit of the plant when raised from self-fertilized seed. The same applies to the various types of *Nicotiana rustica* which we have examined, when grown from self-fertilized seed. No tendency to break up has been noticed, the types breed true in the most remarkable manner and there is no evidence of any transition on the part of the introduced forms towards the coarse-leaved sorts cultivated in Bihár. Excessive amounts of nitrogenous manure and over-watering have a marked effect on the vigour and

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1 Shamel & Cobey, *Bull.* 96, *Bureau of Plant Industry, U. S. Department of Agriculture* 1907, p 11.

2 Killebrew & Myrick, *Tobacco Leaf*, New York, 1900, p. 30.

3 Lock, *Tobacco growing, curing and manufacturing*, London 1903, p. 32.

coarseness of growth of the plants concerned, but this rankness has not been found to be transmitted in any degree to the succeeding crop raised under more normal conditions.

There appears to be a considerable confusion of ideas in much of the literature on this crop as to the effect of environment on the tobacco plant. That *free flowering* tobaccos, introduced into a new district almost always change in type and frequently approximate, after a few years, to the local sorts, has often been observed. The experience in America[1] and our own observations amply prove this. That the physical condition of the soil, cultivation, manuring and climate have the most marked effect on the quality of the cured leaves and their suitability for various purposes cannot be denied. These are principles well known to all tobacco growers. The conditions in Sumatra, for example, favour the production of the best wrapper leaves. Cuba is famous for the aroma and quality of its cigar tobacco, and the various types of tobacco soil in the United States are largely responsible for the various grades produced in that country.

A little consideration will show that in the various modifications to which the tobacco plant is subject, two widely different and distinct kinds of change are involved, namely, (1) changes in the morphological sense, giving rise to the breaking up of the type and the formation of an uneven stand due to the production of plants varying very considerably in the shape, venation and colour of the leaf, in habit and in earliness and lateness, and (2) changes in the size, quality, and texture of the leaves of any particular kind and their suitability for various purposes. As has been indicated, variations in both these directions are possible in introducing a tobacco into a new locality. It is necessary therefore to attempt to understand the causes which bring about the changes in the type itself and also in the quality of the type. As has already been stated, no changes in the uniformity of the type have been observed in the Indian tobaccos grown at Púsa when raised from self-fertilized seed. On the other hand, when the

[1] Shamel & Cobey, l. c.

types are allowed to flower and seed freely at Púsa, the uniformity of the type is soon lost and the crop consists of a mixture of very diverse forms. Our investigations show that in all cases so far examined such variation in the type is the result of one cause only, namely, natural cross-fertilization. If crossing is prevented and the various races are raised from self-fertilized seed, the inheritance of all the characters down to the most minute shades of difference is most marked. The observations and experiments at Púsa point to natural cross-fertilization being the sole cause of changes in the race in the morphological sense. Soil, climate, moisture and food materials, no doubt, influence the quality and suitability of the leaf for various purposes, but we have not found these causes lead to the breaking up of the type.

Most observers agree that natural cross-fertilization occurs in this species, but the extent to which it takes place when the types are grown next to next does not appear to be fully realised. The collection of Indian tobaccos made at Púsa in 1905 was grown for two years on the Púsa farm, and a few plants of each kind were allowed to flower freely in 1906 and again in 1907. In 1907, we selected all the different types in this collection, and saved the seed from each plant separately. The various sowings were made by us in the Botanical area at Púsa the same year and since that time all seeds used to propagate the cultures have been selfed and raised under bag. Opportunities for natural crossing were possible, therefore, at Púsa for two seasons only, and these opportunities were limited by the fact that but few plants of each kind were allowed to flower and the period of flowering of the various kinds did not in all cases overlap. In 1908, observations were made on the uniformity of the cultures raised from one parent plant, and any individuals which varied from the rest in the slightest degree were noted. In every case these aberrant plants were selfed and grown the next year when they gave rise to a large number of forms, often very diverse in habit and in leaves and which were obviously the products of natural cross-fertilization (Plate I). In over a hundred cultures of this species in 1908, about 20 per cent. of the rows contained aberrant plants,

THE PROGENY OF A SELF-FERTILIZED ABERRANT PLANT.
AN EXAMPLE OF THE RESULT OF NATURAL CROSS-FERTILIZATION.

PURE LINE CULTURES OF N. TABACUM AT PUSA, 1909.

thus showing to what a great extent natural crossing is possible when the various kinds are grown in close proximity and allowed to flower freely. Some of the aberrant plants only differed very slightly from the rest of the culture and much care was necessary to distinguish them. Sometimes they appeared only a little more robust than the rest, but in the case of every plant which showed the slightest variation in 1908, its progeny, after bagging, gave rise to uneven cultures made up of many different types.

Too much emphasis cannot be laid on the difficulty of observing the first generation of a cross between two kinds of tobacco in the field. The differences between many tobacco types are exceedingly small and can only be detected with precision after considerable study of such types when grown side by side and allowed to flower. Crosses between types, unless they are very different, would not be easy to observe in the F_1 generation even in cultures from single plants. In the field, where the great majority of the plants are topped, these differences would, in all probability, be overlooked. In the second and succeeding generations, when splitting takes place, the various types resulting from crossing could for the first time be observed.

In great contrast to the variable character of the progeny of a selfed aberrant plant is the great uniformity of the produce obtained from the seed of an ordinary plant raised under bag. In Plate II some of these constant pure line cultures are shown. These cultures afford a means of observing the occurrence or otherwise of mutations and also of the amount of variation that occurs in the types of tobacco. No mutations have been observed and every case of variation from the type has so far been proved to be due to natural crossing. These cultures show the remarkable uniformity of the plants of any particular type both in the same year and also from year to year.

From the practical point of view the significance of natural cross-fertilization is very great. The desirable types of tobacco grown in any district or introduced from other places must be self-fertilized if the quality of the type is to be maintained. The seed sown must have been raised under bag. Where a large number of

kinds are grown at an experimental farm, the greatest care will have to be taken to keep the types pure and to prevent intercrossing. To what extent intercrossing takes place in the cultivators' fields is not known at present, but the matter is now being taken up.

III. CLASSIFICATION AND DESCRIPTION OF THE TYPES.

1. Morphological characters.

The Indian types of *Nicotiana tabacum* show a much greater range in their morphological characters than do the forms of *Nicotiana rustica*, described in a previous paper. In many cases the differences in habit and in leaves are most marked. On the other hand, some of the forms resemble each other very closely and can only be distinguished by small differences in the leaves. It is sometimes impossible to be sure from one season's crop whether the differences are sufficient to differentiate such forms into separate types. Further study has, however, generally shown both that such small differences are wonderfully constant, persisting from year to year (see types XLI and XLII), and also that small differences in leaf shape, etc., are often combined with small differences in the structure and mode of pollination of the flowers (see types III and IV). Great difficulty has been experienced in expressing in words the differences in the shape of the leaves, and this has been increased by the fact that the shape (generally due to a diminution in the width and size of the leaves) often changes considerably from the base of the plant upwards. It is hoped that the photographs will make up for any deficiency in the descriptions.

Habit.

The various Indian types of *Nicotiana tabacum* differ considerably in habit. These differences are caused mainly by the change in the length of the successive internodes of the plant. They are accentuated by differences in the number, position and size of the leaves and by the arrangement of the inflorescence.

It will be best to consider these points in the order of their economic importance :—

(1) *Differences in the lengths of the successive internodes.* As regards this point, the 51 types can be arranged in an almost perfect series, the two extremes being represented by types XIX and LI. In types such as XIX the internodes are exceedingly short and the large leaves are borne so low down that most of them lie on the ground. In other forms the lowest internodes are short, but the succeeding internodes elongate gradually. In such cases many of the large leaves are borne near the ground, but a few moderate-sized ones are borne up the stem (see types V, X, XI, and XII). The plants in group II, class B, (b) (types XXXI, XXXII, XXXIII, and others) deserve special mention, for although they fall into this habit class, in their case the very short lower internodes are followed immediately by very long internodes, and this gives the group a characteristic appearance. Following on the cases in which the lowest internodes are short and the upper ones elongate gradually, we come to forms in which all the internodes are of equal length and the leaves are therefore borne at regular intervals up the stem. In such forms the only leaves lying on the ground are the two or three earliest formed leaves which are generally slightly different in shape to the rest. Good examples of this are types XVII, XLIII, and LI. The height of the plants is closely connected with the length of the internodes and varied in the 1909 crop from 78 cms. (type VII) to 188 cms. (type XXXIII). The actual height of a type in any year will, of course, vary with the conditions of nutrition and season.

The economic importance of the above differences in habit is very great, for in types such as XIX in which all the leaves are in contact with the soil for the whole or part of their length, the value of the cured product will be much depreciated by the dust and dirt which unavoidably clings to the leaves. Such leaves are also very liable to get damaged and torn, and surface cultivation is rendered difficult. In tall forms such as LI where the leaves are borne up the stem, the leaves are very liable to be torn by the wind,

especially in such localities in the plains where west winds or storms are prevalent while the tobacco crop is ripening.

(2) *Number, size and arrangement of the leaves.* Besides the differences in the position of the leaves just enumerated, the appearance of the plants is materially affected by the angle of insertion of the leaves. In some cases the leaves occupy a very upright position, the angle of insertion being small, as in type L ; in others the leaves may be practically horizontal (type VIII), or they may bend over at various points, *i.e.*, at the base (type XVI), in the centre (type XXXII) or at the tip (type XXIII).

If the leaves are few in number, the plant has an open appearance (type XXIII), while numerous small leaves (type XLI) or a moderate number of large ones (type XXXIV) combined with a short habit give the plants a bushy appearance.

The economic importance of the size and number of the leaves is obvious.

(3) *Arrangement of the inflorescence.* The chief difference in the arrangement of the inflorescence which affects the appearance of the plant is the position of the former with regard to the leaves. In some forms the flowers are raised on long branches far above the leaves and in such cases the inflorescence is the most conspicuous part of the plant (see types IX, XI and XIX). In other cases the inflorescence does not grow out and the flowers are borne close to the large leaves (see types XXXV and XXXVIII), when the plants appear leafy.

The tendency to the production of side-shoots or suckers varies considerably among the various types. Some throw out few, others many and vigorous side-shoots. In order to allow the plants to manifest this tendency, only the suckers at the base were removed, the rest being allowed to develop. The habit photographs, therefore, show the tendency or otherwise of the types to sucker.

Leaves.

The angle of insertion of the leaves has already been discussed. In considering the leaves attention must be drawn

to the variation in the leaves on the same plant. The first formed leaves (2 or 3 in number) which remain on the ground, whatever the habit, generally do not possess the characteristic shape of the other leaves and must be left out of account. In some types all the remaining leaves, including the inflorescence leaves, are of the same form and only differ in size (types XVI, XLVIII and LI). In others the inflorescence leaves, generally linear, are quite different to the lower leaves, and there is in the latter a gradual change in shape and in the acuteness on the apex according to the position of the leaf of the stem—the upper ones being generally narrower with more acuminate apices than the lower ones (types XII and XIII). The variation is, however, gradual and one of degree only, *e.g.*, elliptical leaves tend to become lanceolate. In the descriptions such gradual changes have been indicated where possible and the photographs and measurements have been taken from the 4th, 5th and 6th leaves.

The leaves may be sessile or petiolate; in the latter case the petiole is invariably alate. The narrow strip of lamina forming the wings is generally very undulate and the width may vary with the position of the leaf on the plant. Thus, in type V the wings are so broad in the upper leaves as to make them appear almost sessile. In the majority of the types the leaves are amplexicaul and decurrent. The breadth of the decurrent strip of lamina and its length varies considerably in the various types, and the latter may be as much as 5 cms. (type LI). Many of the leaves are auriculate, the size of the auricles being characteristic of the type. In the general shape of the leaves the types fall into three classes: (1) those with lanceolate leaves having acuminate apices (types XI, XII and XIX), (2) those in which the leaves are broad in the centre and taper towards both the apex and the base (types XXXI and XXXII), (3) those in which the leaves are elliptical with acute or somewhat obtuse apices, the lamina being somewhat reduced at the base (type XLI, XLVIII and LI). Within each class considerable differences are found, especially in the amount by which the lamina at the base of the leaf is reduced (cf. types XXXVIII and LI).

Another difference which is of use in distinguishing the types is the angle at which the secondary veins arise; this varies from nearly 90° (type XLIV) to 30° (type VIII) and is constant for any one type. For cigar wrapper tobaccos the angle of venation is of great importance. The form of the apex is generally acute or acuminate, but every gradation is found between the almost obtuse apex of type XXXV to the long slender prolongation in type XIX. Very few of the leaves are quite smooth and flat. The margin may be entire or may be regularly and slightly undulate giving the leaves a "frilled" edge (type XXIV) or may be irregularly and more deeply undulate. Besides these sinuations of the margin the whole leaf has often deep, somewhat irregular undulations, especially near the base (type XIV). The surface may be flat or puckered to a varying extent, and the lamina is often raised between the secondary veins, giving the appearance of ridges or folds parallel to the secondary nerves (type XXXII). The flatness or otherwise of the leaf is an important point in determining the value of the cured tobacco for certain purposes and on the whole the Indian tobaccos are characterised by great unevenness of surface. Our experience at Púsa tends to show that the amount of undulation and puckering of the surface depends to some extent on the conditions of cultivation. Further experiments on this point are in progress. The colour and texture also show much greater differences than in *N. rustica;* type LI has the thinnest leaf, while types VI, VII and VIII are exceedingly thick and would probably be useful only for the manufacture of snuff. The length of the leaf varies from 25 cms. (type XLII) to 63 cms. (type VI), the ratio of length to breadth varies from 1·5 (type III) to 4·4 (type VIII). These measurements, taken on the 1909 crop, and also the notes on the texture are only of relative value.

Inflorescence.

The position of the inflorescence has already been discussed in considering the general habit of the plant. No such marked differences in the arrangement of the flowers is found as occurs

between the open and crowded inflorescences in *N. rustica*, but certain of the types are more free flowering than others. The tall types of group B are in general characterised by the paucity of their flowers, while some of the dwarf varieties produce a profusion of blossoms (type XIX). The general shape of the inflorescence depends on the mode of growth of the side branches. These, although always borne in basipetal succession on the main stem, may be short and originate mostly near the top (type LI) or may be very long and spreading (type XXIII), or if the internodes are very short, may all appear to spring from the base of the plant (type XIX). The inflorescence on the main axis always flowers first and the side branches in order from above downwards. The relative length of the side branches to the main axis varies considerably in the different types : (1) the side branches may be of such a length that when in bloom the flowers are at the same level as the flowers on the main axis, and in this case the inflorescence has a flat top (see types XVII and XIX) ; (2) the flowers on the side branches may be higher than those on the main axis (types XLI and XLII) ; or (3) the flowers on the side branches may be at different heights and at a lower level than the main axis when the inflorescence, as a whole, has a "pyramidal" appearance (types XV and XLVIII). These differences in the appearance of the inflorescence, although characteristic of the types, are often lost later on in the capsule stage by the development of further branches due to excessive watering or other conditions. They are best seen when the flowers on the side branches are just opening and the first capsules have been formed on the main axis. The habit photographs of the plants were, as far as possible, taken at this stage, and in all cases these as well as those of the leaves were taken at approximately uniform distances from the camera.

Flowers.

Although at first sight the flowers of *N. tabacum* appear very much alike, there are considerable differences in the details of structure of the calyx and corolla. Such differences occur in

every possible combination and in the 51 types described very few of the flowers are alike in every particular.

Unlike the types of *N. rustica* where the length of the flower was practically constant and only the width varied, the flowers of the types of *N. tabacum* show considerable differences in length. The shortest flowers are found in type IX where the length is 36 mm., the longest in type XI where the length is 50 mm. or more. The usual length of the flowers is about 45 mm. The colour is generally some shade of pink, but in some types the pink colour is confined to the extreme tips of the corolla lobes in the closed bud, the flower itself being quite white. In many cases the pink colour fades and the older flowers are almost or entirely white. In some types the pink colour is very deep and practically does not fade at all (types XXX, XXXII and XXXV).

Calyx. The relative length of the calyx and corolla varies, but the length of the calyx is always between one quarter to one half that of the corolla. The gamosepalous calyx is not markedly asymmetric and the teeth are generally somewhat long and acute. In shape the calyx is generally tubular but in a few types (*e.g.*, XXXVIII, LI and others) it is distinctly globular and inflated.

Corolla. Several differences in the form of the corolla may be noticed. The orifice varies in size from a diameter of 7 mm. (type I) to one of 11 mm. (type VII), but the usual width is 8 to 9 mm. The shape of the corolla (apart from the shape of the limb) depends on the width of the tube, on the width of the throat or dilated portion and on the manner of transition between these two. The tube may be of various widths from the slender tube in type XVI (Plate XVIII) to the broad tubes of types XXXVIII and XLVII (Plates XL and XLVIII). The tube may gradually dilate, giving the corolla a funnel-shaped appearance, or there may be a sudden expansion in which case the corolla appears "bell-shaped." Good examples of bell-shaped corollas are seen in plate XLVIII, types XLI and LI. The limb may be (1) quite entire when it assumes a pentagonal shape (type XXXVIII, Plate XL), (2) almost entire but slightly notched at the junction

of the lobes (type XLVIII, Plate XLVIII), (3) slightly divided (type XXXVII, Plate XL), (4) divided to about half its distance (type XXV, Plate XXIX), (5) deeply divided (type XVII, Plate XVIII). The undivided portion of the limb may be quite flat (type XXXVIII, Plate XL) or may form slight folds or ridges at the line of junction of the lobes (type XLVIII, Plate XLVIII). The shape of the lobes varies somewhat. They may be more or less triangular with somewhat straight margins (type XXXIX, Plate XL) or much rounded at the base (type XVII, Plate XXII). The apex may be acute or prolonged into a point (longer or shorter according to the type), which may be straight or oblique. A good example of such apical points is seen in type XVII (Plate XVIII), type XXXIV (Plate XL), and in type IX (Plate XII).

Capsule. The capsules in the Indian forms of *N. tabacum* vary in size, shape, nature of the apex and in the degree to which they are covered by the persistent calyx. The shape may be cylindrical or conical, the apex blunt or pointed. In some types the capsules have a tendency to fall off when ripe together with the peduncle instead of remaining *in situ* and shedding the seed by dehiscence. In such cases it is necessary to protect any crossed or selfed capsules by a bag just before they are quite ripe.

2. Modes of pollination.

The frequency of cross-pollination in *Nicotiana tabacum* has already been discussed on page 64. Knuth,[1] in his *Handbuch der Blütenbiologie,* drew attention to the fact that the arrangements for pollination differ somewhat in the various races. The pollination of all the Indian types of *Nicotiana tabacum* has been studied to obtain as much information on this point as possible. Of the five stamens, one is always much shorter than the others and is generally well below the stigma. In a few cases, however, it may be long enough for its tip to touch the stigma. The pollen of this stamen is, therefore, negligible for self-fertilization. The remaining four stamens may be approx-

[1] Knuth, *Handbuch der Blütenbiologie,* Bd. II, 1899.

imately equal in length, and this is the most usual arrangement, or one may be shorter than the other three, or there may be 2 long and 2 short stamens.

Pollination may take place in the closed bud or, as is more frequently the case, the anthers burst just as the bud unfolds. In a few cases the anthers burst later when the flower is half expanded. In the time of pollination this species differs from *Nicotiana rustica* in which pollination generally takes place just before the bud opens.

The relative position of the anthers and stigma and consequently the certainty of self-pollination varies in the different types. The anthers may be below the stigma when they burst and may remain always at a lower level than the stigma, making cross-pollination very probable, but this is rare. The most usual arrangement is that in which the ripe anthers surround or are just above the stigma when the flower opens. In the fully opened flowers the burst anthers and stigma may maintain this relative position or the anthers may be as much as 5mm. above the stigma. In some cases the ripe anthers are well above the stigma in the unfolding bud, and in such cases the burst anthers are always far above the stigma in the fully open flower. In one or two types, cases were found in which the ripe anthers surrounded the stigma, but the latter was well above the empty anthers later.

Another striking difference was observed in the position of the stigma and anthers with regard to the orifice of the corolla. In some cases the anthers or stigma project far beyond the corolla opening. This can be seen in the front view of the corolla of type II (Plate III) and of type IX (Plate XII). In other cases the anthers or stigma remain low down in the tube of the corolla. In the majority of the types, the anthers are either level with the corolla orifice or project slightly.

In the majority of the Indian types of N. *tabacum*, self-pollination is somewhat more favoured than cross-pollination, but in none of the types so far examined is crossing practically excluded as in type V of N. *rustica* where the stamens are massed so closely

over the stigma that the latter is never visible. The filaments of N. *tabacum* are much longer and the flowers are larger than in the case of the yellow-flowered tobaccos. In consequence the anthers do not fill up the throat so completely and are not in such close contact with and do not form a ring round the stigma as in the case N. *rustica*. Sometimes the anthers are on one side of the stigma only ; in other cases some are on one side and some on the other. These circumstances affect pollination considerably, and as the flowers lie more or less horizontally, a good deal of pollen is wasted and often falls on the inside of the throat of the corolla. The types in which the stigma is above the stamens never set seed when bagged and have to be selfed.

3. Scheme of classification.

A comprehensive phylogenetic and systematic study of the species *N. tabacum* was made by Comes[1] who collected a large number of the different forms from all parts of the world. From the results of this study he divided the species into six varieties, the distinction between them depending very largely on the shape of the leaves.

(1) var. *fruticosa* Hook.
(2) var. *lancifolia* (W.) Comes.
(3) var. *virginica* (Agdh.) Comes.
(4) var. *brasiliensis* Comes.
(5) var. *havanensis* (Lag.) Comes.
(6) var. *macrophylla* Schrank.

Of these he states that (3) and (4) are no longer to be found in a pure state, but only as hybrids with other varieties.

This subdivision of the species has been vigorously assailed by Anastasia[2], who reduces the number of varieties to four,

[1] Comes, *Monographie du genre Nicotiana*, Naples, 1899 and *Delle razze dei Tabacchi*, Naples, 1905.

[2] Anastasia, *Le varieta tipiche della Nicotiana tabacum*, L., Scafati, 1907.

excluding var. *fruticosa* and var. *lancifolia* and substituting var. *purpurea* for var. *macrophylla*.

The varieties according to Anastasia are therefore as follows :—

var. *havanensis*.
var. *brasiliensis*.
var. *virginica*.
var. *purpurea*.

Recently Comes[1] has published a short answer to the criticisms of Anastasia.

Into the merits of this controversy it is impossible for us to enter as we have not at our disposal in India the material on which the rival systems are founded, and we have, therefore, been unable to make use of either. Moreover, the cultivated forms do not show the characters of any one of these "typical" varieties, but a combination of the characters of two or more. This is referred by Comes to the hybrid nature of the cultivated forms, and in his large work *Delle razze dei Tabacchi* (which is in the main a description of a large number of commercial forms of tobacco from all over the world) he classifies almost all the cultivated forms as hybrids between two or more varieties. Thus Cimanon tobacco from Mexico is classed as a hybrid of *fruticosa* × *brasiliensis* × *havanensis* × *macrophylla*, China tobacco as a hybrid of *fruticosa* × *brasiliensis* × *lancifolia*. Such a classification appears to be open to several objections. In the first place, it gives no handy and workable guide in identifying any particular form, and, secondly, in our present state of knowledge regarding the inheritance of characters in the species *N. tabacum* it is difficult to prognosticate what products such a hybridization of four quite different varieties would yield. It is certain both from theoretical considerations, and from the evidence already obtained from accidental cross-fertilization, that the number of forms obtained would be numerous It does not appear justifiable therefore to state that a form is a hybrid between

[1] Comes, *Bolletino Tecnico*, No. 1, Scafati, 1908

two varieties, unless such has been proved to be the case by actual experiments. Under these circumstances we considered that it would be best to arrange the Indian tobaccos in a provisional scheme of classification based on easily recognizable characters to facilitate identification and reference. The choice of the characters on which to base the classification of the Indian forms of *Nicotiana tabacum* was difficult owing to the manner in which the types grade into one another and form a series. The most promising characters appeared to be habit, shape of the leaf and the similarity or dissimilarity of the inflorescence and lower leaves. It was finally decided to base the main divisions on the leaf characters, using the habit for further subdivisions.

Of the fifty-one Indian types of *N. tabacum*, five may be termed petiolate and are placed in one group. The petioles are always alate and the inflorescence leaves occasionally appear almost sessile, but there is no difficulty in separating the petiolate forms from the others. Only in the case of type VII it must be noted that a few of the median leaves appear stalked. In all the leaves the lamina is much reduced and in a few the reduction is carried so far that only a very narrow strip of lamina runs down the petiole. One of these has been chosen for the photograph. As, however, the sessile character of most of the leaves is clear, the occasional presence of the leaves in which a petiole is simulated should present no difficulty. Whether the leaves termed "petiolate" above should really be considered as leaves in which the lamina is reduced to a minimum does not concern the classification, as the stalked character of the leaves in these types forms an easy mark of distinction. The group of forms with sessile leaves is subdivided into three classes depending on the character of the leaves: (A) forms with long narrow leaves, (B) forms with leaves broad in the centre and tapering towards both ends, (C) forms with leaves broad and elliptical which do not taper at either end. These distinctions hold well on the whole, although both in (B) & (C) there are one or two types which are not absolutely typical (see type XXIII in (B) and type

XXXIV in (C)). These classes are further subdivided according to the habit.

I. Leaves petiolate.

A. Leaves ovate.

Types I, II.

B. Leaves subcordate.

Types III, IV, V.

II. Leaves sessile.

A. Lower leaves linear or lanceolate ; ratio length to breadth 3 to 4 ; inflorescence leaves linear.

(1). Leaves linear, very thick ; ratio length to breadth more than 4.

Types VI, VII, VIII.

(2). Leaves lanceolate, not very thick, ratio length to breadth between 3 and 4.

(*a*) Internodes short ; all the large leaves form a rosette on the ground.

Type IX.

(*b*) Lower internodes short, upper gradually lengthened ; many large leaves borne on the ground, a few continued up the stem.

Types X, XI, XII, XIII.

(*c*) All the internodes moderately long ; only 2 or 3 leaves on the ground.

Types XIV, XV, XVI, XVII, XVIII.

B. Lower leaves broad in the centre, tapering towards both ends ; ratio length to breadth between 2 & 3 ; inflorescence leaves linear or similar to, but narrower than, the lower leaves.

(1). Internodes short; all the large leaves form a rosette on the ground.

Type XIX.

(2). Lower internodes short, upper internodes moderately long; some large leaves on the ground, others on the stem; leaves numerous; plants bushy.

Types XX, XXI, XXII.

(3). Lower internodes short, upper internodes very long; most of the large leaves borne on the ground; plants tall; inflorescence open with few flowers.

Types XXIII, XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, XXX, XXXI, XXXII, XXXIII.

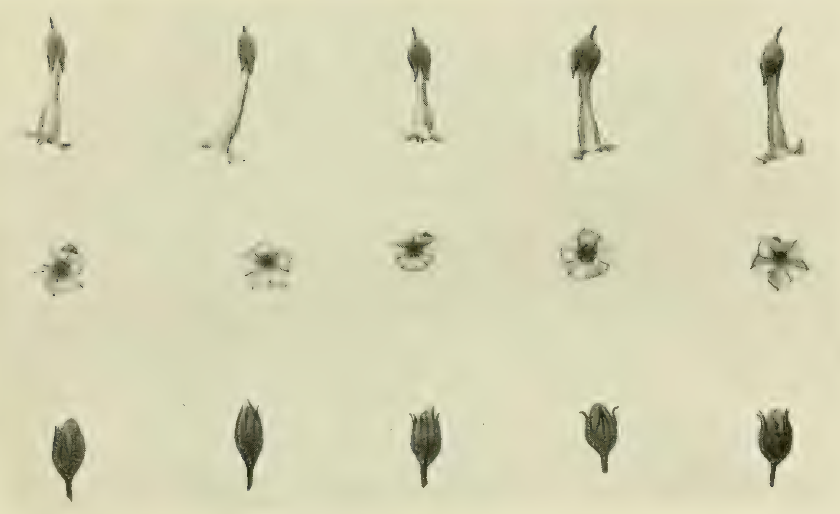
C. Leaves elliptical, broad, apex acute; lamina at the base only slightly reduced; ratio length to breadth about 2; inflorescence leaves always similar to the lower leaves.

(1). Lower internodes short, upper internodes moderately long.

Types XXXIV, XXXV, XXXVI, XXXVII, XXXVIII, XXXIX, XL.

(2). All the internodes equal in length and moderately long.

Types XLI, XLII, XLIII, XLIV, XLV, XLVI, XLVII, XLVIII, XLIX, L, LI.



TYPE II. I. III. IV. V.

FLOWERS AND CAPSUSLES.

4. Description of the types.

Group I. Plants with petiolate leaves.

The five types included in this group fall into two classes :—

(A) Forms with ovate leaves, types I and II.

(B) Forms with subcordate leaves, types III, IV, V.

Types I and II resemble each other slightly, but are easily distinguished by the much smaller size of the leaves in type I and its more bushy habit.

Types III and IV are very coarse tall forms. The leaves are almost cordate and very puckered. On superficial inspection III and IV appear to be identical, but they differ in several details connected with the texture of the leaf and the structure of the flower (see description of type IV).

Type V is most easily distinguished from III and IV by its short habit, light green colour, thin texture and the flat surface of its leaves. The leaves in type V are not as cordate as in types III and IV. Types III, IV and V were all obtained from Burma.

Type I. Plants late, tall ; height 143 cms. ; the leaves are many, and are all borne in the lower half of the plant, giving it a very bushy appearance ; practically no leaves lie on the ground. *Leaves* petiolate, petioles slightly alate, much more so in the upper leaves ; wings decurrent for about 2·5 cms. down the main stem ; leaves inserted at an angle of 60°—90°, tending to stand out horizontally, ovate, the upper ones narrower than the lower ones ; venation acute-angled ; secondary veins arising at an angle of 60° ; apex acute ; margin with slight regular undulations ; surface somewhat puffy ; colour dark green ; texture medium ; average length of petiole 3 cms. ; average length of lamina 33 cms. ; ratio length/breadth 2·0. *Inflorescence leaves* petiolate, inserted at an angle of 90°, lanceolate ; apex acuminate ; margin undulate ; surface flat. *Inflorescence* much raised and very conspicuous ; side branches borne at regular intervals all up the main stem, almost as long as the main axis and very spreading. *Flowers* few, a deep pink colour which fades slightly ; length 48 mm. *Calyx* tubular, slightly inflated, less than one-third the length of the corolla; teeth short and acute. *Corolla* very slender and with a very narrow orifice ; diameter 7 mm. ; the transition between the tube and the dilated portion very gradual, the latter not much wider than the tube ; limb slightly divided with folds at the junctions of the lobes ; lobes rounded at the base with long straight apical points. *Capsule* equal in length to the persistent calyx, conical ; apex blunt.

The anthers burst in the bud and occupy a position just above the stigma. In the fully open flower the burst anthers maintain this position and slightly project from the orifice of the corolla.

TYPE I.

Type II. Plants late, tall; height 150 cms.; lower internodes short, upper ones long; most of the large leaves borne near the ground; no large leaves in the upper two-thirds of the plant. *Leaves* petiolate, petiole is slightly alate in the lower leaves, more so in the upper ones; the wings are decurrent down the main stem for about 2·5 cms.; leaves inserted at an angle of 90° and bend downwards from the top of the petiole, asymmetric; shape varies from ovate to lanceolate according to the position on the stem; venation acute-angled, secondary veins arising at an angle of 45°—60°; apex acute; margin entire or slightly undulate; colour blue-green; texture thick; average length of petiole 6 cms.; average length of lamina 49 cms.; ratio length/breadth 2·5. *Inflorescence leaves* petiolate, petiole not alate, inserted at an angle of 60°—90°, lanceolate; apex acuminate; margin generally entire, sometimes undulate. *Inflorescence* raised, side branches borne at regular distances up the stem, parallel to but not as long as the main axis. *Flowers* a deep pink colour which does not fade much; length 45 mm. *Calyx* slightly globular and inflated, about one-third the length of the corolla; teeth moderately long and acute. *Corolla* with an orifice 8 mm. in diameter, a broad tube, and the transition between the tube and the dilated portion abrupt; limb not very deeply divided with folds at the junctions of the lobes; lobes very rounded at the base; apical points short and somewhat reflexed. *Capsule* much longer than the persistent calyx, conical; apex blunt.

The anthers burst as the flower expands, not in the bud, and at this period are above the stigma. In the fully open flower the burst anthers are about 5 mm. above the stigma and project well beyond the orifice of the corolla.

TYPE II.

Type III. Plants very late, tall; height 150 cms.; lower internodes very short, upper internodes long; some of the lowest leaves lie on the ground, the others are borne at long intervals up the stem. *Leaves* petiolate with alate petioles, the wings of the petiole expand on reaching the stem and are amplexicaul and decurrent for 5 cms.; leaves inserted at an angle of about 60° and bend downwards; shape ovate to cordate; secondary veins arise at an angle of more than 60°; apex acute; margin undulate; leaf undulate; surface puckered; texture thick; colour dark blue green; average length of petiole 5 cms.; average length of leaf 41 cms.; ratio length / breadth 1·5. *Inflorescence leaves* petiolate with very short alate petioles, inserted at an angle of 90°, ovate; apex acuminate; leaf undulate and surface generally puckered. *Inflorescence* with few flowers and with very spreading sideshoots which arise at regular intervals on the upper half of the main stem. The side branches bear very few flowers. *Flowers* pink, the colour easily fades; length 42 mm. *Calyx* globular and inflated, less than one-third the length of the corolla; teeth moderately long and acute. *Corolla* with a broad tube and short dilatation, diameter of orifice 8 mm; the transition between the tube and the expanded portion abrupt; limb not very deeply divided; lobes much rounded, pointed but with no distinct apical points. *Capsule* much shorter than the persistent calyx, conical; apex blunt.

The anthers burst as the flower expands, not in the bud, and occupy a position above the stigma. In the fully open flower, the burst anthers are about 5 mm. above the stigma and project much beyond the orifice of the corolla.

Type IV. Resembles type III exactly except in the following points :—

(1) The leaves are smoother.

(2) The calyx is more inflated.

(3) The lobes of the corolla are mucronate.

(4) The capsule is shorter and broader and about equal in length to the persistent calyx.

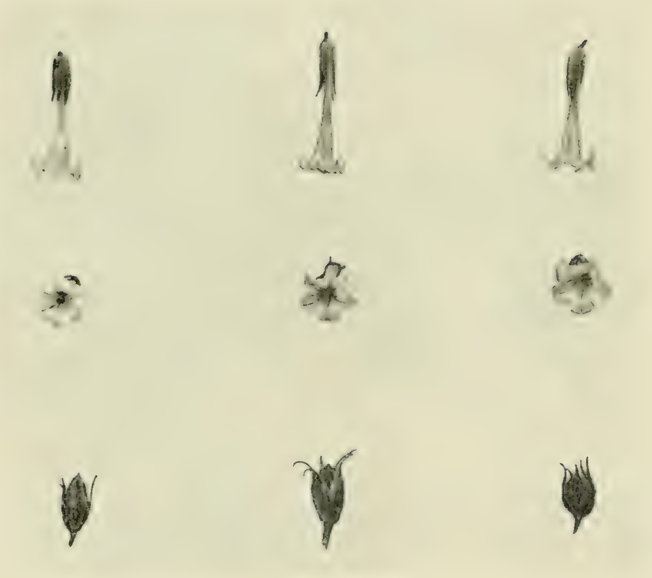
(5) The anthers are only slightly raised above the stigma.

TYPE IV.

Type V. Plants somewhat late, not very tall ; height 127 cms. ; lower internodes short causing most of the leaves to be crowded at the base of the plant, a few are borne up the stem. *Leaves* very large and conspicuous, petiolate with alate petioles, the wings are amplexicaul and decurrent on the main stem ; leaves inserted at an angle of about 90° and bend downwards from the base of the petiole ; shape of the lower leaves subcordate, of the upper leaves elliptical ; secondary veins arise at an angle of 60—90° ; apex acute ; margin slightly undulate ; surface very slightly puckered ; colour light green ; texture thin to medium ; average length of petiole 5 cms. ; average length of leaf 45·5 cms. ; ratio length / breadth 1·6. *Inflorescence leaves* petiolate with very short alate petioles, ovate or elliptical ; apex acute ; margin slightly undulate ; surface flat. *Inflorescence* not conspicuous, side branches as long as the main axis, somewhat spreading. *Flowers* a deep pink colour which fades somewhat ; length 45 mm. *Calyx* tubular, inflated, about one-third the length of the corolla ; teeth moderately long and acute. *Corolla* with a very broad tube, almost as broad as the dilatation, the transition between the tube and the dilated portion very gradual ; limb not deeply divided ; lobes rounded at the base, pointed but with no apical points. *Capsule* slightly longer than the persistent calyx, conical ; apex blunt.

The anthers burst in the bud when just below the stigma. In the fully open flower the burst anthers are below the stigma and the latter is level with the orifice of the corolla.

TYPE V.



TYPE VIII. VI. VII.

FLOWERS AND CAPSULES.

Group II. Plants with sessile leaves.

Class A. Lower leaves linear or lanceolate; ratio length to breadth 3 to 4·5; inflorescence leaves linear.

This class contains thirteen types of narrow-leaved tobaccos. Several of the kinds are dwarf forms and no very tall types occur. For several reasons it seems probable that the economic value of the tobaccos in this class is not very high. In the majority of the forms, the leaves are borne on or near the ground, and this causes them to be torn or damaged easily, especially those with long, slender tips. They are also liable to be much deteriorated by contact with the soil. Moreover, the leaves are generally undulating not flat and the midrib is pronounced and thick.

Sub-class 1. Leaves linear and very thick; ratio length to breadth more than 4.

The three types contained in this sub-class are most distinctive and can be easily recognised by their exceedingly thick needle-like leaves. The leaves are dark green with conspicuous light-coloured veins and stand out stiffly and horizontally. They are of no value except for the manufacture of snuff. The three types are easily distinguished among themselves by differences in habit.

Type VI. Plants somewhat early, dwarf; height 80 cms.; lower internodes very short, so that all the large leaves form a rosette on the ground. *Leaves* sessile with a tendency to droop from near the base, inserted at an angle of 90°, lanceolate (lamina narrowed towards the base but not as much as in types VII and VIII), auriculate, slightly amplexicaul and sometimes slightly decurrent; secondary veins arise at an angle of 30°, apex acuminate; margin entire, except for very occasional slight undulations at the base of some of the lowest leaves; surface flat; colour dark green; veins much lighter green; texture thick average length 63 cms.; ratio length to breadth 4·1. *Inflorescence leaves* sessile, inserted at an angle of 90° but droop somewhat, linear, somewhat broader than in types VII and VIII; apex acuminate; margin entire and surface flat, but leaf sometimes undulate at the base. *Inflorescence* less crowded with leaves than in type VIII and with fewer sideshoots, these lie close to the main stem and surpass it in length. *Flowers* very pale pink when opening, white when fully open; length 50 mm. *Calyx* loose but not globular, about half the length of the corolla or less, somewhat deeply divided. *Corolla* with an orifice 9 mm. in diameter; tube 6 mm. wide; the transition between the tube and the dilated portion somewhat abrupt; limb not so deeply divided as in types VII and VIII; lobes not rounded at the base; apical points long and straight. *Capsule* cylindrical; apex pointed; the persistent calyx much longer than the capsule.

Pollination appears to take place in the same manner as in type VIII. The stamens and stigma never reach the orifice of the corolla.

TYPE VI.

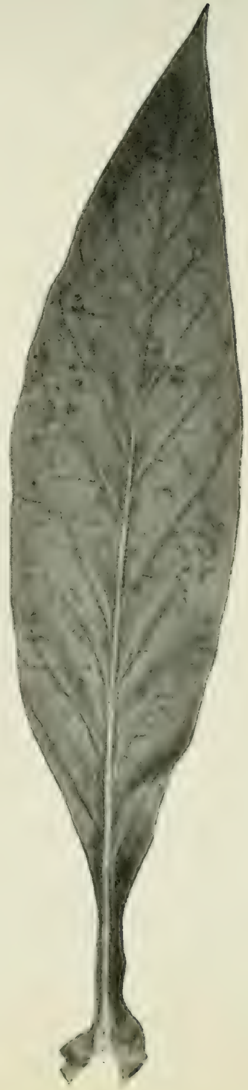
Type VII. Plants somewhat early, dwarf; height 78 cms.; owing to the shortness of the lower internodes: the large leaves, which are few in number, are borne near the ground. *Leaves* sessile, inserted in the lower half of the plant at an angle of 90°, in the upper half at an angle of 60°, stiff, thick, do not droop unless flaccid, lanceolate (lamina much narrowed towards the base of the leaf), lower leaves very slightly amplexicaul; venation acute-angled, secondary veins arising at an angle of 30°; apex acuminate; margin entire, except for very occasional slight undulations at the base of some of the lowest leaves; surface flat; colour dark green; veins much lighter green: average length 55 cms.; ratio length / breadth 4-1. *Inflorescence leaves* sessile, inserted at an angle of 45°, linear; apex acuminate; margin generally entire and surface flat, but occasionally the leaf is more or less undulate. *Inflorescence* quite different from that of type VIII, being crowded with linear leaves, which give the plant a bushy appearance, and with many side shoots which arise near the base of the plant and are parallel to and as long as or longer than the main stem. *Flowers* very pale pink when opening, white with pink edges to the petals when fully open; length about 45 mm. *Calyx* somewhat loose but not globular, about half the length of the corolla or less, somewhat deeply divided. *Corolla* with a wide orifice (11 mm.) and a broad tube (6 mm.), the transition from the tube to the dilated portion gradual; limb deeply divided and reflexed; lobes rounded at the base; apical points medium in length and often twisted to one side. *Capsule* short and broad; apex somewhat round; the persistent calyx teeth longer than the capsule.

In the unopened bud the stamens are above the stigma and burst in the bud or just as the flower opens. When the flower is fully open, the stigma is above the anthers which are already empty. Both stigma and anthers project slightly beyond the orifice of the corolla.

TYPE VII.

Type VIII. Plants somewhat early, dwarf; height 115 cms.; internodes equal in length and moderately long, the stiff horizontal leaves thus borne at regular intervals up the stem give the plant a very characteristic appearance. *Leaves* sessile, inserted at an angle of 90°, upper ones at an angle of 60°, stiff and thick, do not droop unless flaccid, auriculate, slightly amplexicaul and decurrent, lanceolate (lamina diminishing to a varying extent at the base of the leaf); venation acute angled, secondary veins arising at an angle of 30°; apex acuminate; margin entire, except for very occasional slight undulations at the base of some of the lowest leaves; surface flat; colour dark green, veins much lighter green; average length 60 cms.; ratio length / breadth 4·4. *Inflorescence leaves* sessile, inserted at an angle of 60° to 90°, linear; apex acuminate; margin entire; surface flat. *Inflorescence* with side shoots not as long as the main axis, at first somewhat parallel to the main stem, later somewhat spreading. *Flowers* a deep pink colour at first which fades later to a pale pink; length about 48 mm. *Calyx* tubular, a little less than half as long as the corolla; calyx teeth somewhat long. *Corolla* slender, diameter of the orifice 10 mm., width of the tube 5 mm., the transition between the tube and the dilated portion abrupt; limb deeply divided; lobes rounded at the base; apical points short. *Capsule* long, somewhat narrow, almost covered by the persistent calyx; apex rather pointed

The ripe anthers burst in the bud or as the flower opens when they are just above the stigma. In the open flower the anthers are just above the stigma and the latter is covered with pollen. The anthers and stigma are level with the orifice of the corolla.



TYPE VIII.

TYPE IX. XIII. XII. XI. X.

FLOWERS AND CAPSULES,

Sub-class 2. Leaves lanceolate; ratio length to breadth between 3 and 4. The types contained in this sub-class form, as regards habit; a series of which the two extremes are the dwarf form, type IX, with all its leaves forming a rosette on the ground, and type XVII in which the leaves are arranged at regular intervals up the stem, none being on the ground. This sub-class can be conveniently divided into three sub-divisions according to the habit; type XIII may be considered as a transition form between sub-divisions (*b*) and (*c*).

(*a*) Internodes short; all the large leaves form a rosette on the ground.

Only one type (IX) belongs to this sub-division. It is readily distinguished from the other types of this sub-class by the habit and by the peculiar crinkling of the inflorescence leaves.

Type IX. Plants early, dwarf; height 104 cms.; lower internodes very short, causing nearly all the large leaves to lie on the ground. *Leaves* sessile, inserted at an angle of 90°, slightly amplexicaul, lanceolate, lamina much narrowed towards the base; venation acute-angled, secondary veins arising at an angle of 30°; apex acuminate, median leaves prolonged into very long thin points; margin and lamina with deep undulations, lamina raised between the secondary veins, giving the appearance of folds or ridges; colour dark green; texture very thick; average length 56 cms.; ratio length/breadth 3·6. *Inflorescence leaves* sessile, inserted at an angle of 90° and droop downwards from the base, linear; apex acuminate; the whole leaf is very sinuate and sometimes even twisted. *Inflorescence* conspicuous and raised above the leaves, with numerous side shoots which are almost as long as the main axis and not very spreading. *Flowers* a very pale pink colour, short (36 mm.). *Calyx* tubular with long and acute teeth, more than half as long as the corolla. *Corolla* with a wide orifice (11 mm.), and a broad tube, the transition between the tube and the dilated portion somewhat gradual; limb divided to about half its depth; lobes rounded at the base; apical points short, straight and only slightly reflexed. *Capsule* cylindrical with a somewhat blunt apex; persistent calyx longer than the capsule.

In the unopened bud, all the stamens are below the stigma. The anthers burst just as the flower opens while they are still below the stigma or at the most touch the underside with their apices. In the open flowers the stigma is much above the burst anthers and all project beyond the orifice of the corolla. In some of the buds the stigma is visible between the still closed lobes of the corolla.

TYPE IX.

(*b*) Lower internodes short, upper ones gradually elongated; many large leaves borne close to the ground, a few continued up the stem.

Of the four types belonging to this sub-division type XIII forms a transition between sub-divisions (*b*) and (*c*). Only a few leaves are borne on the ground and several large ones appear on the main stem. In its open habit this type resembles types XIV and XV.

Type X is a short bushy form easily distinguished from the other types in this sub-division by its height and the surface of its leaves. Types XI and XII resemble each other very closely and only differ in some minor details. Type XII is later than type XI with deep pink flowers, while the flowers of the latter are white. The structure of the flowers is also somewhat different.

Type X. Plants early, very short; height 106 cms.; many of the large leaves form a rosette on the ground, but several are borne up the main stem, giving the plant a slightly bushy appearance. *Leaves* sessile, inserted at an angle of 60° to 90° but droop downwards from about the centre of the leaf, slightly decurrent, slightly auriculate; shape lanceolate, breadth varies according to the position on the stem; lamina narrowed towards the base; venation acute-angled, secondary veins inserted at an angle of about 45°; apex acute to acuminate; the margin only may be undulate, or the whole leaf may be undulate, especially the base of the upper leaves; colour light green; texture thick; average length 54 cms.; ratio length / breadth 4·1. *Inflorescence leaves* sessile, inserted at an angle of 60° to 90°, linear, undulate at the base or quite flat; apex acuminate. *Inflorescence* somewhat raised, side branches almost as long as the main axis. *Flowers* a pale pink colour which soon fades; length 45 mm. *Calyx* tubular, somewhat inflated, less than half the length of the corolla; teeth moderately long and very acute. *Corolla* with an orifice 8 mm. in diameter, the transition between the tube and the dilated portion abrupt; limb divided to about half its depth; lobes rounded with pointed apices, but no long apical points. *Capsule* a little shorter than the persistent calyx, slightly conical; apex somewhat pointed.

The anthers burst while the flower is expanding when they surround the stigma. The anthers and stigma maintain their relative positions in the fully open flower and are opposite the orifice of the corolla.

TYPE X.

Type XI. Plants early; height 120 cms.; nearly all the large leaves form a rosette on the ground, but some are borne on the lower half of the stem. *Leaves* sessile, inserted at an angle of 60° or more, and bend downwards at a point very near the base of the leaf, auriculate, amplexicaul, lanceolate, the breadth of the leaf diminishing and the apex becoming more acuminate in passing from the base upwards; lamina narrowed towards the base of the leaf; venation acute angled, secondary veins arising at an angle of 45°; apex acuminate; margin and lamina with irregular undulations which increase with the position of the leaf up the stem; colour dark blue-green; texture medium to coarse; average length 52 cms.; ratio length / breadth 3·5. *Inflorescence leaves* sessile, inserted at an angle of about 90°, linear; apex acuminate; margin and lamina generally undulate. *Inflorescence* raised and open, side branches borne at regular intervals up the stem, not so long as the main axis and somewhat parallel to it. *Flowers* white with a faint pink tinge in the buds; length 50 mm or more. *Calyx* tubular, about one-third the length of the corolla: teeth long and acute. *Corolla* slender, tube long and the transition between this and the dilated portion very gradual; limb deeply divided with folds at the junctions of the lobes; lobes rounded at the base with long, reflexed, apical points. *Capsule* small, a little shorter than the persistent calyx, cylindrical; apex blunt.

In the bud the ripe anthers are just above the stigma and burst in the bud or as the flower expands. In the open flower the empty anthers are a long distance above the stigma and project just beyond the orifice of the corolla.

TYPE XI.

Type XII. Plants early, but later than type XI; height 129 cms.; nearly all the large leaves form a rosette on the ground, but some are borne on the lower half of the stem; plants more leafy than in type XIII. *Leaves* sessile, inserted at an angle of 60° or more, and bend downwards from a point very near the base of the leaf, auriculate, slightly amplexicaul, shape varies with the position on the stem and may be ovate, elliptical or lanceolate, lamina much narrowed towards the base; venation acute-angled, secondary veins arising at an angle of 30° to 45°; apex acuminate; margin and lamina undulate; colour somewhat blue-green; texture medium to thick; average length 58 cms; ratio length/breadth 3·3. *Inflorescence leaves* sessile, inserted at an angle of more than 90°, linear; apex acuminate; surface sometimes flat, sometimes undulate. *Inflorescence* raised and open, side branches borne at regular intervals up the stem, not as long as the main axis and somewhat spreading. *Flowers* a deep pink colour which does not fade much; length 47 mm. *Calyx* tubular, somewhat inflated; teeth long and acute. *Corolla* with an orifice 8 mm. in diameter, the transition between the tube and the dilated portion slightly abrupt; limb deeply divided; lobes much rounded at the base with straight, moderately long apical points. *Capsule* a little shorter than the persistent calyx, cylindrical, with a blunt apex.

The ripe anthers surround the stigma and burst as the flower opens. In the open flower the burst anthers and stigma are practically level with each other and also with the orifice of the corolla.

TYPE XII.

Type XIII. Plants early; height 137 cms.; habit open with few large leaves, some form a rosette on the ground, others are borne on the lower half of the stem. *Leaves* sessile, inserted at an angle of more than 60° and bend towards the ground from a point in the centre of the leaf, slightly auriculate (lower leaves more auriculate than the upper ones), slightly amplexicaul; shape varies according to the position of the leaf and may be ovate, elliptical or lanceolate, lamina narrowed towards the base; venation acute-angled, secondary veins arising at an angle of about 45°; apex acuminate; lamina with deep irregular undulations which become more marked on the leaves borne towards the upper portion of the stem, lower leaves practically flat; colour light green; texture medium; average length 54 cms.: ratio length/breadth 3·0. *Inflorescence leaves* sessile, inserted at an angle of 90°, linear: apex acuminate; lamina often very undulate, sometimes flat. *Inflorescence* raised, side branches arise at long intervals up the main stem; they are not as long the main axis and remain somewhat parallel to the latter. *Flowers* a deep pink colour which soon fades; length 45 mm. *Calyx* tubular; teeth long and acute. *Corolla* with an orifice 8 mm. in diameter, the transition between the tube and the dilated portion abrupt; limb deeply divided; lobes rounded at the base with moderately long, straight apical points. *Capsule* shorter than the persistent calyx, cylindrical, with a blunt apex.

The anthers burst in the bud while surrounding the stigma. In the open flower the anthers are slightly above the stigma and both project from the orifice of the corolla.

TYPE XIII.

TYPE XVIII. XV. XIV. XVII. XVI.

FLOWERS AND CAPSULES.

(*c*) All the internodes moderately long, only two or three leaves on the ground.

Five types (XIV to XVIII) belong to this sub-division. The first three are easily distinguished from the other two by their much greater height, and the greater elongation of their inflorescence. Type XIV bears some resemblance to type XIII of the last sub-division and is distinguished from XV and XVI by the width and paucity of its leaves. Types XV and XVI are very easily distinguished from each other by the shape and surface of their leaves, type XV having more undulate leaves with more acuminate apices than type XVI. Type XVII is a short type with a peculiarly flat-topped inflorescence and very few leaves. The most distinctive character of type XVII is the shape of its leaves in which it shows a resemblance to class B.

Type XIV. Plants early, fairly tall; height 143 cms.; internodes with the exception of the lowest ones moderately long, so that few leaves are borne close to the ground, and the majority are borne up the stem; leaves more numerous than in types XV and XVIII. *Leaves* sessile, inserted at an angle of 90°, but hang vertically downwards from a point near the base of the leaf, slightly amplexicaul, lower leaves slightly decurrent, lanceolate, lamina slightly narrowed towards the base; venation acute-angled, secondary veins arising at an angle of 30° to 45°; apex acuminate; margin slightly undulate, lower leaves flat or slightly undulate, these undulations increase in the upper leaves; colour blue-green; texture medium; average length 48 cms.; ratio length/breadth 3·8. *Inflorescence leaves* sessile, inserted at an angle of 60° to 90°, linear; apex acuminate; lower half of the leaf very undulate. *Inflorescence* raised; side branches borne at regular intervals up the stem, not as long as the main axis, spreading. *Flowers* a deep pink colour which does not fade, long owing to the unusual length of the corolla tube (length 50 mm.). *Calyx* globular, about one-third the length of the corolla; teeth long and acute. *Corolla* with an orifice 8 mm. in diameter, slender, the transition between the tube and the dilated portion gradual; limb deeply divided, but with no folds; lobes much rounded at the base; apical points long and oblique. *Capsule* a little shorter than the persistent calyx, small, conical; apex pointed.

In the unopened bud the anthers are slightly below the stigma. The ripe anthers burst while the flower is expanding when they surround the stigma. In the open flower the burst anthers surround the stigma or are just below it and all project beyond the orifice of the corolla.

TYPE XIV.

Type XV. Plants early, tall ; height 143 cms. ; habit open ; internodes moderately long, except the two or three lowest ones, so that nearly all the leaves are raised above the ground. *Leaves* sessile, inserted at an angle of about 90° and bend downwards from about the centre of the leaf, amplexicaul, very slightly decurrent, auriculate, lanceolate, shape varies with the position of the leaf on the stem, lamina much narrowed for a short distance above the base (in a few leaves the lamina is reduced to a very narrow strip); venation acute-angled, secondary veins arising at an angle of 30° to 45° ; apex acuminate ; margin and lamina somewhat undulate especially near the base of the leaf ; colour light green ; texture medium ; average length 57 cms. ; ratio length/breadth 3·1. *Inflorescence leaves* sessile, inserted at an angle of 90° (apices droop downwards), linear, lamina at the base much reduced ; apex acuminate ; margin undulate and the basal third of the leaf very undulate. *Inflorescence* much raised ; side branches borne at regular intervals on the upper half of the stem, spreading, shorter than the main axis. *Flowers* white, very pale pink in the bud ; length 45 mm. *Calyx* tubular and inflated, less than half the length of the corolla ; teeth long and acute. *Corolla* with a wide orifice (10 to 11 mm.), the transition between the tube and the dilated portion somewhat gradual ; limb deeply divided with folds at the junction of the lobes ; lobes much rounded at the base ; apical points very long. *Capsule* a little shorter than the persistent calyx, large, conical ; apex blunt.

In the unopened bud the anthers are above the stigma and burst just as the flower opens when they are still more raised. In the fully open flower the burst anthers are some distance above the stigma and are nearly level with the orifice of the corolla.

TYPE XV.

Type XVI. Plants somewhat early ;-height 141 cms. ; habit very open, internodes long, only 2 or 3 leaves lie on the ground. *Leaves* sessile, inserted at an angle of 90° and droop downwards from near the base, amplexicaul, sometimes slightly auriculate, decurrent, lanceolate, lamina slightly narrowed at the base; secondary veins arise at an angle of 30° to 45° ; apex acuminate ; margin entire ; lamina flat except for occasional slight undulations at the base of some of the leaves; colour very light green ; texture medium ; average length 46 cms. ; ratio length/breadth 4·1. *Inflorescence leaves* similar to the lower leaves but much narrower, in some cases linear, and the undulations at the base are more marked. *Inflorescence* raised with long side branches which are somewhat parallel to and not as long as the main axis. *Flowers* few in number pale pink ; length 50 mm. *Calyx* tubular, somewhat inflated, about one-third the length of the corolla ; teeth long and acute. *Corolla* slender, with an orifice 8 mm. in diameter ; tube slender, the transition between the tube and the dilated portion slightly abrupt ; limb divided to about half its depth ; lobes rounded at the base ; apices very pointed but no apical point. *Capsule* shorter than the persistent calyx, conical ; apex pointed.

The anthers burst in the bud when level with the stigma. In the fully open flowers the empty anthers are just above the stigma and generally slightly project from the orifice of the corolla.

TYPE XVI.

Type XVII. Plants early, short; height 103 cms.; internodes moderately long; leaves borne at regular intervals up the stem, none lie on the ground. *Leaves* sessile, inserted at an angle of 90° or more and droop from the base, amplexicaul, slightly auriculate and slightly decurrent, elliptical or lanceolate; secondary veins arise at an angle of 45° to 60°; apex acuminate; margin slightly undulate, some of the leaves with deep undulations at the base; surface flat; colour blue green; texture medium; average length 39 cms.; ratio length/breadth = 2·8. *Inflorescence leaves* sessile, inserted at an angle of 90° or more, linear; apex acuminate; leaves flat or with a few undulations at the base. *Inflorescence* conspicuous and raised, side branches stout, very spreading, as long as the main axis. *Flowers* numerous, white; length 45 mm. *Calyx* tubular, inflated, a little less than half the length of the corolla; teeth long and acute. *Corolla* with an orifice 9 mm. in diameter, tube broad, the transition between the tube and the dilated portion gradual; limb divided to about half its depth, folded at the junctions of the lobes; lobes rounded at the base with long apical points which are sometimes oblique. Many of the corollas were monstrous in this type in 1908 and 1909. *Capsule* shorter than the persistent calyx, conical; apex pointed.

The anthers burst in the bud and are then just above the stigma. In the open flower the stigma and empty anthers maintain their relative positions and are much below the orifice of the corolla.

TYPE XVII.

Type XVIII. Plants somewhat early, later than types XIV and XV, dwarf; height 97 cms.; habit open; internodes moderately long, except the two or three lowest ones, so that nearly all the leaves are raised above the ground. *Leaves* sessile, inserted at an angle of about 60° and droop from a point about one-third from the base of the leaf; shape varies from elliptical to lanceolate according to the position of the leaf on the stem, lamina much narrowed in the basal third of the leaf; leaves slightly amplexicaul, decurrent for about 1·5 cms., slightly auriculate; venation acute-angled, secondary veins arising at an angle of about 45°; apex acute to acuminate; margin slightly undulate, the lamina more or less undulate in the basal portion according to the position of the leaves on the stem; colour light green; texture thin; average length 45·5 cms.; ratio length/breadth 3·0. *Inflorescence leaves* sessile, inserted at an angle of 90°, linear; apex acuminate; margin entire or slightly undulate; leaf flat or somewhat undulate. *Inflorescence* raised above the leaves; side branches borne at regular intervals up the stem from the base upwards, almost as long as, and somewhat parallel to, the main axis. *Flowers* white, very pale pink in the bud, short (length 40 mm.). *Calyx* tubular, less than half the length of the corolla; teeth moderately long and acute. *Corolla* with a very small orifice (7 mm.), slender; the transition between the tube and the dilated portion abrupt; limb deeply divided with folds at the junctions of the lobes; lobes very rounded at the base; apical points short. *Capsule* a little shorter than the persistent calyx, conical; apex pointed.

The anthers burst in the bud when just above the stigma. In the open flower the stamens are decidedly above the stigma and project beyond the orifice of the corolla.

TYPE XVIII.

TYPE XIX. XX. XXI. XXII.

FLOWERS AND CAPSULES.

Class B. Lower leaves broad in the centre, tapering towards both ends ; ratio length to breadth between 2 and 3 ; inflorescence leaves linear or similar to, but narrower than, the lower leaves.

This class contains 15 types and is intermediate in character between class A with very narrow lower leaves and linear inflorescence leaves, and class C in which the lower and inflorescence leaves are broad. The leaves of all the types are alike in being decidedly broad in the centre, but the amount of tapering towards both ends differs somewhat. The types are further subdivided according to habit.

Sub-class 1. Internodes short ; all the large leaves form a rosette on the ground.

Only one type belongs to this sub-class. It is a very free flowering form with broad leaves prolonged into long slender points.

Type XIX. Plants early, dwarf; height 83 cms.; lower internodes exceedingly short, causing all the lower leaves to lie on the ground. *Leaves* sessile, inserted at an angle of 90°, very slightly amplexicaul, the lower leaves very slightly auriculate, elliptical, lamina suddenly narrowed a short distance above the base (in some of the upper median leaves the lamina is practically absent in the lower portion); venation acute-angled, secondary veins arising at an angle of less than 30°; apex acuminate and prolonged into a long point which is often curved to one side; margin with slight regular undulations, the whole lamina deeply undulated and raised between the veins forming folds; colour dark green; texture thick; average length 52 cms.; ratio length/breadth 2·4. *Inflorescence leaves* sessile, inserted at an angle of 90°, linear; apex acuminate; margin slightly undulate, lamina undulate. *Inflorescence* very conspicuous, and raised above the leaves; side shoots numerous, shorter than the main axis and very spreading. *Flowers* a deep pink colour which does not fade, 45 mm. in length. *Calyx* tubular with long acute teeth, less than half as long as the corolla. *Corolla* slender with an orifice 9 mm. in diameter and a narrow tube, the transition between the tube and the dilated portion very gradual; lobes much rounded at the base with long straight points which are reflexed. *Capsule* short, somewhat broader above than below with a blunt apex; the persistent calyx very slightly longer than the capsule, but the calyx teeth stand away from the capsule and do not cover it.

The ripe anthers are just below or surround the stigma and burst as the flower expands. In the open flower the stigma is just above the burst anthers, and both stamens and stigma project slightly beyond the orifice of the corolla.

TYPE XIX.

Sub-class 2. Lower internodes short, upper internodes moderately long ; some large leaves on the ground, others up the stem ; leaves numerous ; plants bushy.

Two of the types included in this sub-class are dwarf forms, the third type (XXII) is somewhat tall. The leaf of this latter type is not quite as typical of the class as that of the others, but its general habit supports its inclusion. Type XXI is an exceedingly bushy form with numerous leaves, quite different to type XX, where the habit is open, although the plant is so short. Type XXII has a large leaf of good colour and texture, but is somewhat late.

Type XX. Plants somewhat early, dwarf; height 102 cms.; lower internodes very short, causing nearly all the large leaves to lie on the ground. *Leaves* sessile, inserted at an angle of 90° and droop from a point near the base, slightly amplexicaul, lower leaves broad and ovate, the upper ones more lanceolate, lamina much narrowed towards the base; venation acute-angled; secondary veins arising at an angle of 30°: apex acute; margin with large shallow undulations; lamina raised between the secondary veins, giving the appearance of folds; colour light green; texture thick; average length 56 cms.; ratio length/breadth 2·6. *Inflorescence leaves* sessile: inserted at an angle of 90° or more and droop from the base, linear; apex acuminate; margin almost entire; surface flat. *Inflorescence* raised far above the leaves; side shoots few and not as long as the main stem, very spreading. This combined with the paucity of the inflorescence leaves gives the plant a very open appearance. *Flowers* pale pink when opening, white when open; length 40 mm. *Calyx* tubular, more than half the length of the corolla; teeth long and acute. *Corolla* with a narrow orifice (diameter 8 mm.) and a broad tube, the transition between the tube and the dilated portion very gradual; limb not deeply divided; lobes somewhat rounded, with very short straight points. *Capsule* cylindrical and somewhat blunt, quite covered by the long foliaceous teeth of the persistent calyx, which project far above the apex.

The ripe anthers burst as the flower opens when they are just above the stigma. In the open flower the anthers and stigma are approximately at the same level as the orifice of the corolla.

TYPE XX.

Type XXI. Plants early, dwarf; height 85 cms.; lower internodes short so that most of the large leaves lie on the ground, but the plants have a leafy, bushy appearance on account of the large number of medium-sized leaves borne on the numerous side branches. *Leaves* sessile, inserted at an angle of about 90° and droop downwards at a point about one-third from the base, slightly amplexicaul and sometimes slightly auriculate, the shape varies, lower leaves ovate or elliptical, upper ones ovate or lanceolate, lamina generally much narrowed towards the base; venation acute-angled, secondary veins arising at an angle of 30°; apex acuminate with a long slender point; margin very undulate, lamina with deep undulations and raised between the veins, giving the appearance of folds; colour dark green; texture thick; average length 52 cms.; ratio length/breadth 2·8. *Inflorescence leaves* sessile, inserted at an angle of 60° to 90° and droop downwards at a point one-third from the base, lanceolate to linear; apex acuminate ending in a long thread-like point; margin and lamina very undulate. *Inflorescence* not exceedingly conspicuous or raised; side branches spring from the base, and are longer than the main axis, somewhat spreading and bear many leaves. *Flowers* pink, the colour does not fade; length 45 mm. *Calyx* tubular, length less than half that of the corolla; teeth long and acute. *Corolla* very slender, diameter of the orifice 8 mm., the transition between the tube and the dilated portion slightly abrupt; limb deeply divided; lobes rounded at the base with long straight apical points which are reflexed. *Capsule* cylindrical, with pointed apex; calyx longer than the capsule.

In this type the anthers do not burst until the corolla begins to expand. In the unopened bud the anthers at first surround the stigma and later are raised above it. In the open flower the stigma is always below the stamens and below the opening of the corolla. The longest stamens project beyond the orifice of the corolla.

TYPE XXI.

Type XXII. Plants rather late, short but not dwarf; height 117 cms.; many of the large leaves form a rosette on the ground, but some are borne on the lower half of the stem. The raising of the inflorescence above the leaves gives this type an open appearance and distinguishes it from type XXI. *Leaves* sessile, inserted at an angle of 45°, but the upper half of the leaf bends over until it is horizontal, slightly amplexicaul; secondary veins arise at an angle of 45°; shape ovate, upper leaves ovate-lanceolate, lamina narrowed for a very short distance above the base; apex acuminate; margin with shallow regular undulations, otherwise lamina and surface flat; colour light green; texture thin; average length 54 cms.; ratio length/breadth 2·3. *Inflorescence leaves* sessile, inserted at an angle of 60° to 90°, lanceolate to linear; apex acuminate; margin entire and leaf flat. *Inflorescence* raised above the leaves and conspicuous, side branches arise some distance above the base and are not as long as the main axis. *Flowers* a deep pink colour which fades slightly, very long (length 50 mm.). *Calyx* somewhat globular, about one-third the length of the corolla, somewhat inflated. *Corolla* slender, diameter of the orifice 8 mm., the transition between the tube and the dilated portion gradual; limb deeply divided; lobes rounded at the base and pointed at the apex, with a short apical point. *Capsule* much longer than the persistent calyx, conical; apex pointed.

The anthers do not burst until the corolla is expanding when they surround the stigma or are slightly above it. In the fully open flower the burst anthers are slightly above the stigma and level with the orifice of the corolla.

TYPE XXII.

TYPE XXIII. XXIV. XXX. XXXII. XXXI. XXXIII. XXV. XXVI. XXVIII.

FLOWERS AND CAPSULES.

Sub-class 3. Lower internodes short, upper internodes very long, most of the large leaves borne on the ground, plants tall, inflorescence open with few flowers.

This is a well-defined group of tall tobaccos. Eleven types are contained in it, of which no less than nine are from Bihár. They are characterised by their height, lateness, the sparseness and deep pink colour of the flowers, open character of the inflorescence and the peculiar folding over at the midrib of the leaves. Types XXIII and XXIV are not as typical of this group as the other forms. These eleven types may be distinguished among themselves by differences in the shape of the leaf, number of branches, and by the amount of crumpling or puckering of the leaf surface. Types XXVIII & XXIX are easily distinguished from all the others by the glossy surface of their leaves and the light colour of the veins. They are almost identical, but differ so markedly in time of flowering that it was necessary to maintain them as separate types. Type XXVIII was obtained from Bihár and type XXIX from the Central Provinces.

Type XXIII. Plants somewhat early; height 136 cms.; leaves few, lower internodes short, causing some of the leaves to be borne very near the ground, upper internodes long; inflorescence raised in a few long slender branches. *Leaves* sessile, inserted at an angle of 90° and bend downwards from near the base, amplexicaul, very slightly decurrent, elliptical, lamina slightly narrowed towards the base; secondary veins arise at an angle of nearly 90°; apex acuminate; margin and base of leaf undulate; surface puckered; leaf not fully expanded but folded on the midrib; colour yellowish green; texture thick; average length 46 cms.; ratio length/breadth 2·5. *Inflorescence leaves* similar to the lower leaves but narrower. *Inflorescence* raised on a few, long, spreading branches. *Flowers* few, pale pink; length 45 mm. *Calyx* tubular, somewhat inflated, a little less than half the length of the corolla; teeth moderately long and acute. *Corolla* with an orifice 8 mm. in diameter; tube broad, the transition between the tube and the dilated portion somewhat abrupt; limb divided to about half its depth; lobes not rounded at the base; apical points long and sometimes oblique. *Capsule* shorter than the persistent calyx, cylindrical; apex blunt.

The anthers burst in the bud or as the flower is expanding and are then just above the stigma. In the fully open flower the empty anthers and the stigma maintain their relative positions and are level with the orifice of the corolla.

TYPE XXIII.

Type XXIV. Plants very late; height 149 cms.; lower internodes very short, causing some of the leaves to lie on or near the ground, upper internodes long; inflorescence raised on the main axis, with secondary branches at the top only. *Leaves* sessile, inserted at an angle of 45°, bending over to become more or less horizontal, amplexicaul, slightly auriculate, decurrent for about 2·5 cms., elliptical, lamina narrowed for a short distance above the base; secondary veins arise at an angle of 60° or more; apex acuminate; margin with slight regular undulations; surface puckered and raised between the secondary veins; colour blue-green; average length 52 cms.; ratio length/breadth 2·6. *Inflorescence leaves* similar to the lower leaves but lanceolate and with occasional deep undulations at the base. *Inflorescence* much raised on the main axis with a few spreading side-branches borne near the apex. *Flowers* pink; length 45 mm. *Calyx* tubular, somewhat inflated, a little less than half the length of the corolla; teeth long and acute. *Corolla* with an orifice 8 mm. in diameter, and a broad tube, the transition between the tube and the dilated portion slightly abrupt; limb divided to about half its depth, with small folds at the junctions of the lobes; lobes much rounded at the base; apical points short. *Capsule* slightly shorter than the persistent calyx, cylindrical; apex pointed.

The anthers burst as the bud expands when just level with or just above the stigma. In the open flower the stigma and anthers are in the same relative positions and are level with the orifice of the corolla.

TYPE XXIV.

Type XXV. Plants very late, tall ; height 165 cms. ; leaves few ; lower internodes very short, a few leaves borne on the ground, upper internodes very long ; inflorescence much raised on long slender branches ; flowers sparse. *Leaves* sessile, inserted at an angle of 60°, the upper half becoming horizontal, amplexicaul, slightly auriculate, decurrent, the decurrent portion very narrow ; shape elliptical, lamina reduced in the basal fifth of the leaf ; secondary veins arise at an angle of 45° ; apex acute ; margin with deep irregular undulations ; surface puckered ; leaf not expanded but folded on the midrib ; colour yellowish green ; texture coarse to medium ; average length 54 cms. ; ratio length/breadth 2·8. *Inflorescence leaves* similar to the lower leaves, but narrower and not amplexicaul or decurrent. *Inflorescence* much raised on long slender branches, which are parallel to the main stem. *Flowers* sparse, a very deep pink colour which does not fade ; length 45 mm. *Calyx* tubular, inflated, less than half the length of the corolla ; teeth moderately long and acute. *Corolla* with a wide orifice (11 to 12 mm. in diameter), tube broad, the transition between the tube and the dilated portion gradual ; limb divided to about half its depth, fully expanded with folds at the junctions of the lobes ; lobes rounded at the base with very short apical points. *Capsule* equal in length to the persistent calyx, cylindrical ; apex blunt.

The anthers burst as the flower expands when they are approximately level with the stigma. The stigma and empty anthers retain their relative positions in the fully open flower and are level with the orifice of the corolla.

TYPE XXV.

Type XXVI. Plants late, tall ; height 175 cms. ; leaves few ; lower internodes very short, causing some leaves to lie on the ground, upper internodes very long ; inflorescence much raised on numerous long slender branches ; flowers sparse. *Leaves* sessile, inserted at an angle of about 60° and droop downwards from a point near the base, slightly amplexicaul and auriculate, decurrent, the decurrent portion very narrow ; shape ovate, lamina reduced in the basal fifth of the leaf ; secondary veins arise at an angle of 45° ; apex acute ; margin with large irregular undulations ; surface puckered ; leaf not expanded but folded on the midrib ; colour light green ; texture coarse ; average length 53 cms. ; ratio length/breadth 2·4. *Inflorescence leaves* similar to the lower leaves. *Inflorescence* much raised on long slender branches, which are somewhat spreading in habit. *Flowers* sparse, a very deep pink colour which does not fade ; length 45 mm. *Calyx* tubular, slightly inflated, a little less than half the length of the corolla ; teeth moderately long and acute. *Corolla* with an orifice 8 mm. in diameter and a fairly broad tube, the transition between the tube and the dilated portion gradual ; limb divided to about half its depth, not fully expanded, with folds at the junctions of the lobes ; lobes rounded at the base with short apical points. *Capsules* approximately equal in length to the persistent calyx, cylindrical ; apex blunt.

The anthers burst as the flower expands when they are approximately level with the stigma. In the fully open flower the empty anthers and the stigma maintain their relative positions and are nearly level with the orifice of the corolla.

TYPE XXVI.

Type XXVII. Plants late, tall; height 163 cms.; leaves neither few nor very numerous; lower internodes very short, causing some of the leaves to lie on the ground, upper internodes very long; inflorescence much raised on long slender branches; flowers sparse. *Leaves* sessile, inserted at an angle of about 60°, the upper portion tending to become horizontal, slightly amplexicaul and auriculate, decurrent, the decurrent portion very narrow; shape ovate, lamina reduced in the basal fifth of the leaf; secondary veins arise at an angle of 45°; apex acuminate; margin and lamina very undulate (more so than in type XXVI); surface very puckered; leaf not expanded but folded on the midrib; colour light green; texture coarse; average length 55 cms.; ratio length/breadth 2·6. *Inflorescence leaves* similar to the lower leaves but narrower. *Inflorescence* much raised on long, slender, spreading branches. *Flowers* sparse, a deep pink colour; length 45 mm. *Calyx* tubular, inflated, less than half the length of the corolla; teeth moderately long and acute. *Corolla* with a wide orifice (11 to 12 mm.), and a broad tube, the transition between the tube and the dilated portion gradual; limb divided to about half its depth, fully expanded with folds at the junctions of the lobes; lobes rounded at the base with very short apical points. *Capsule* equal in length to the persistent calyx, cylindrical; apex blunt.

The anthers burst as the flower expands when they are approximately level with the stigma. In the fully open flower the stigma and empty anthers retain their relative positions and are level with the orifice of the corolla.

TYPE XXVII.

Type XXVIII. Plants very late, tall ; height 159 cms. ; leaves numerous ; plants bushy ; lower internodes very short, causing many leaves to lie on or near the ground, upper internodes very long ; inflorescence much raised on numerous long, slender branches ; flowers sparse. *Leaves* sessile, inserted at an angle of about 45°, and bend downwards from the centre of the leaf, amplexicaul, decurrent for 4 to 7·5 cms., the decurrent strip of lamina very narrow ; shape elliptical ; breadth of the leaf decreasing with its position up the stem, lamina much reduced in the basal third of the leaf ; apex acuminate ; secondary veins arise at an angle of 45°, veins much lighter in colour than the lamina, and therefore very conspicuous ; margin very undulate ; surface puckered, lamina raised between the secondary veins, giving the appearance of folds or ridges ; leaf not expanded but folded on the midrib ; colour glossy bright green ; texture medium to thick ; average length 50 cms. ; ratio length/breadth 2·5. *Inflorescence leaves* very similar to the lower leaves except as regards their shape which is lanceolate. *Inflorescence* much raised on long slender branches which are somewhat spreading in habit. *Flowers* sparse, a very deep pink colour which does not fade ; length 45 mm. *Calyx* tubular, inflated, a little less than half the length of the corolla ; teeth short and acute. *Corolla* with an orifice 8 mm. in diameter, and a fairly broad tube, the transition between the tube and the dilated portion gradual ; limb divided to about half its depth with folds at the junctions of the lobes ; lobes rounded at the base ; apical points short ; limb never fully expanded. *Capsule* a little longer than the persistent calyx, cylindrical ; apex blunt.

The anthers burst in the bud when just above or just level with the stigma. In the open flower they maintain their relative positions and are below the orifice of the corolla.

Type XXIX resembles type XXVIII in every particular, but is much earlier in flowering.

TYPE XXVIII.

Type XXX. Plants late, tall ; height 163 cms. ; leaves numerous ; plants bushy ; lower internodes very short, causing many leaves to lie on or near the ground, upper internodes very long ; inflorescence much raised on numerous long, slender branches ; flowers sparse. *Leaves* sessile, inserted at an angle of about 60°, the upper portions tending to become horizontal, amplexicaul, auriculate, decurrent for about 4 cms., the decurrent portion being first broad, then narrow ; shape elliptical, the lamina reduced during the basal fifth of the leaf ; apex acuminate ; secondary veins arise at an angle of 45° ; margin with very slight undulations ; surface almost flat ; leaf not expanded but folded on the midrib ; colour yellowish green ; texture thin ; average length 54 cms. ; ratio length/breadth 2·4. *Inflorescence leaves* very similar to the lower leaves, except as regards their shape which is lanceolate. The lamina at the base of these leaves is also often deeply undulate. *Inflorescence* much raised on long, slender branches which are somewhat spreading in habit. *Flowers* sparse, a very deep pink colour which does not fade ; length 50 mm. *Calyx* tubular, somewhat inflated, about one-third the length of the corolla ; teeth moderately long and acute. *Corolla* with an orifice 9 mm. in diameter, and a somewhat broad tube, the transition between the tube and the dilated portion very gradual ; limb divided to about half its depth with folds at the junctions of the lobes ; the lobes rounded at the base ; apical points short. *Capsule* equal in length to the persistent calyx, cylindrical and blunt.

The anthers burst as the flower expands while they surround or are slightly above the stigma. In the open flower the burst anthers and stigma maintain their relative positions and are below the level of the orifice of the corolla.

TYPE XXX.

Type XXXI. Plants very late, tall; height 177 cms.; leaves numerous; plants very bushy; lower internodes very short, causing many leaves to lie on or close to the ground, upper internodes long; inflorescence raised on long branches which bear numerous small leaves. *Leaves* sessile, inserted at an angle of about 60°, the upper part bending downwards, amplexicaul, auriculate, decurrent for about 2·5 cms.; shape ovate to elliptical, the lamina reduced in the basal fifth of the leaf; secondary veins arise at an angle of 45° to 60°; apex acuminate; lamina with irregular deep undulations (but less so than in type XXXII); surface puckered and ridged between the secondary veins; leaf not expanded but folded on the midrib; colour yellowish green; texture medium (thinner than type XXXII); average length 53 cms.; ratio length/breadth 2·1. *Inflorescence leaves* similar to the lower leaves. *Inflorescence* raised on long branches which are parallel and equal in length to the main axis. *Flowers* sparse, a deep pink colour which does not fade; length 45 mm. *Calyx* tubular, somewhat inflated, about one-third the length of the corolla; teeth short and acute. *Corolla* with an orifice 9 mm. in diameter, tube medium, the transition between the tube and the dilated portion somewhat abrupt; limb divided to about half its depth, fully expanded with folds at the junctions of the lobes; lobes rounded at the base with short apical points. *Capsule* equal in length to the persistent calyx, cylindrical; apex blunt.

The anthers burst while the flower expands when they are just above the stigma. In the fully open flowers the burst anthers occupy the same relative position to the stigma and project from the orifice of the corolla.

TYPE XXXI.

Type XXXII. Plants very late, tall; height 179 cms.; leaves numerous; plants bushy; lower internodes very short, causing many leaves to lie on or near the ground, upper internodes very long; inflorescence raised on long branches bearing many small leaves; flowers sparse. *Leaves* sessile, inserted at an angle of 60°, the upper half of the leaf bends downwards, amplexicaul, auriculate, decurrent for 3 to 4 cms., ovate to elliptical, the lamina reduced in the basal fifth of the leaf; secondary veins arise at an angle of 60°; apex acuminate; lamina with deep irregular undulations; surface very puckered and ridged between the secondary veins; leaf not expanded but folded on the midrib; colour rather light yellowish green; texture medium; average length 51 cms.; ratio length/breadth 2·1. *Inflorescence leaves* similar to the lower ones but narrower. *Inflorescence* raised on long branches which are parallel and equal in length to the main axis. *Flowers* sparse, a deep pink colour which does not fade; length 45 mm. *Calyx* tubular, inflated, a little less than half the length of the corolla; teeth moderately long and acute. *Corolla* with an orifice 9 mm. in diameter, tube medium, the transition between the tube and the dilated portion gradual; limb divided to about half its depth, fully expanded with folds at the junctions of the lobes; lobes much rounded at the base with short apical points. *Capsule* slightly longer than the persistent calyx, conical; apex blunt.

The anthers burst while the corolla is expanding, when they are at first round and later above the stigma. In the fully open flower the burst anthers are above the stigma and almost on a level with the corolla opening.

TYPE XXXII.

Type XXXIII. Plants very late, tall, bushy; height 188 cms.; leaves numerous; lower internodes very short, causing many leaves to lie on or near the ground, upper internodes long; inflorescence raised on long branches which bear many small leaves. *Leaves* sessile, inserted at an angle of about 60°, the upper part bending downward, amplexicaul, auriculate, decurrent for about 2·5 cms.; shape ovate to elliptical, the lamina reduced in the basal fifth of the leaf; secondary veins arise at an angle of 45° to 60°; apex acuminate; leaf with irregular very deep undulations; surface very puckered and ridged between the secondary veins; leaf not expanded but folded on the midrib; colour yellowish green; texture medium; average length 51 cms.; ratio length/breadth 1·9. *Inflorescence leaves* similar to the lower leaves. *Inflorescence* raised on long branches which are equal in length to the main axis and somewhat spreading. *Flowers* sparse, a deep pink colour which does not fade; length 45 mm. *Calyx* somewhat globular, inflated, about one-quarter the length of the corolla; teeth short and somewhat acute. *Corolla* with an orifice 9 mm. in diameter, tube medium, the transition between the tube and the dilated portion somewhat abrupt; limb divided to about half its depth, fully expanded with folds at the junctions of the lobes; lobes rounded at the base with short apical points. *Capsule* approximately equal in length to the persistent calyx, conical; apex blunt.

The anthers burst just as the bud opens and then surround or are slightly above the stigma. In the fully open flowers the stigma is generally a little above the burst anthers (or it may be level with them) and level with or projecting slightly beyond the orifice of the corolla.

TYPE XXXIII.

TYPE XXXVI. XXXVIII. XL. XXXIX. XXXIV. XXXVII. XXXV.

FLOWERS AND CAPSULES.

Class C. Leaves elliptical, broad ; lamina at the base only slightly reduced ; apex acute : ratio length to breadth about 2 : inflorescence leaves always similar to the lower leaves.

This class contains the types which will probably prove the most valuable. The leaves are broad, large and the midribs are not so pronounced as in class A. The distinctive feature is the shape of the leaves which is broad throughout and only slightly narrowed for a very short distance above the base. The broad inflorescence leaves are also very characteristic. On the whole the inflorescence is not much raised, nor as free flowering as in class A, while the more compact form of the plants with large leaves continued up the stem is very different to the open habit and basal crowding of the leaves in class B.

Sub-class I. Lower internodes short, upper internodes moderately long.

Of the seven types included in this sub-class type XL is not very typical, but appeared to be nearer the types in this class than those of any other. Type XXXVI with linear inflorescence leaves is also somewhat anomalous, but the shape of the lower leaves necessitated its inclusion here rather than in class B. Type XXXIV with its very long leaves and type XXXV with exceedingly broad leaves are most distinctive and very easily recognised in the field. Type XXXVII in the shape of its leaves is not absolutely typical. The small angle of inset of the leaves and their flatness and stiffness are characteristic of this form. Type XXXVIII has a peculiarly shaped corolla in which the dilated portion is exceedingly short and the tube very broad. No other type among the Indian tobaccos has a corolla of this shape. Type XXXIX is somewhat like XXXVIII in habit, but is easily distinguished from the latter by the leaf shape.

Type XXXIV. Plants late, short ; height 112 cms. ; lower internodes short, almost all the large leaves are borne on or near the ground, upper internodes long, but the leaves borne up the main stem are comparatively small. *Leaves* sessile, inserted at an angle of 60° to 90° and stand out more or less horizontally, auriculate, amplexicaul, decurrent, elliptical, lamina not narrowed at the base ; secondary veins arise at an angle of 60° to 90° ; apex acuminate with a long, slender point which is sometimes curved ; margin slightly undulate ; surface slightly raised between the secondary veins and sometimes puckered ; colour dark blue-green ; texture medium ; average length 58 cms. ; ratio length/breadth 2·2. *Inflorescence leaves* similar to the lower leaves. *Inflorescence* not conspicuous with several long side branches which are somewhat spreading and not as long as the main axis. *Flowers* few, pale pink in colour ; length 40 mm. *Calyx* globular, inflated, a little less than half the length of the corolla ; teeth short and acute. *Corolla* with an orifice 8 mm. in diameter, and a broad tube, the transition between the tube and the dilated portion slightly abrupt ; limb divided to about half its depth with folds at the junctions of the lobes ; lobes rounded at the base ; apical points long and sometimes oblique. *Capsule* slightly shorter than the persistent calyx, cylindrical ; apex blunt.

The anthers burst as the bud opens and are then well above the stigma. In the fully open flower the burst anthers are 5 mm. above the stigma and are approximately level with the orifice of the corolla.

TYPE XXXIV.

Type XXXV. Plants somewhat early, short with exceedingly broad leaves; height 106 cms.; internodes very short, several leaves lie on the ground. *Leaves* sessile, inserted at an angle of 60° afterwards becoming horizontal, auriculate, amplexicaul, decurrent for about 1 cm., the decurrent portion of the lamina being very broad, elliptical; secondary veins arise at an angle of 90°; apex acute; margin with slight regular undulations; surface puckered; colour blue-green; texture thin; average length of leaf 48 cms.; ratio length/breadth 1·5. *Inflorescence leaves* resemble the lower leaves in every particular but are smaller. *Inflorescence* inconspicuous, scarcely raised and much hidden by the large leaves; side branches few, short and spreading. *Flowers* large, a very deep pink colour which does not fade; length 50 mm. *Calyx* globular, inflated, about one-third the length of the corolla; teeth short and obtuse. *Corolla* with an exceedingly broad tube; diameter of the orifice about 10 mm.; transition between the tube and the dilated portion abrupt; limb entire with slight indentations between the lobes which have no apical points. *Capsule* equal in length to the persistent calyx, broad, conical; apex blunt.

The anthers and stigma are at the same level both in the expanding bud and in the fully open flower. The anthers burst just as the flower opens. Both anthers and stigma remain just below the level of the corolla orifice.

TYPE XXXV.

Type XXXVI. Plants early, dwarf ; height 100 cms. ; most of the large leaves form a rosette on the ground owing to the shortness of the lower internodes, but some fairly large leaves are borne up the stem and give the plant a bushy, leafy appearance. *Leaves* sessile, inserted at an angle of 90°, and droop downwards, elliptical, lamina very slightly narrowed towards the base, slightly auriculate, amplexicaul ; venation acute-angled, secondary veins arising at an angle of 45 to 60° ; apex acuminate ; margin with regular slight undulations, but leaf and surface flat ; colour blue-green ; texture thin ; average length 47 cms. ; ratio length/breadth 2·0. *Inflorescence leaves* sessile, inserted at an angle of 90° and droop towards the ground, lanceolate to linear ; apex acuminate ; margin slightly undulate. *Inflorescence* not very conspicuous ; side branches arise near the base and are not as long as the main axis, very spreading. *Flowers* a pale pink colour which fades to white ; length 45 mm. *Calyx* globular, less than half the length of the corolla ; teeth long and acute. *Corolla* with a broad tube, orifice 9 mm. in diameter, the transition between the tube and the dilated portion somewhat abrupt ; limb slightly divided with folds between the lobes ; lobes much rounded ; apical points short and straight. *Capsule* conical with a blunt apex ; calyx longer than the capsule.

The anthers burst while surrounding the stigma, later the burst anthers are found far above the stigma. Only the longest stamens reach the orifice of the corolla.

TYPE XXXVI.

Type XXXVII. Plants somewhat early, short; height 107 cms.; lower internodes short; many of the large leaves are borne near the ground but a few are borne up the main stem; leaves numerous and large. *Leaves* sessile, inserted at an angle of 45 to 60°, slightly auriculate, slightly amplexicaul, decurrent for about 5 cms., elliptical, lamina narrowed in the basal fourth of the leaf; secondary veins arise at an angle of 60° or more; apex acute; margin generally entire and flat but occasionally regularly and slightly undulate; surface sometimes slightly raised near the edge; colour dark green; texture thick; average length 48 cms.; ratio length/breadth 2·7. *Inflorescence leaves* similar to the lower leaves but lanceolate in shape and with acuminate apices. *Inflorescence* many-flowered with long side shoots which are not as long as the main axis. *Flowers* pink; length 45 mm. *Calyx* globular, inflated, about one-third the length of the corolla; teeth short and acute. *Corolla* with a wide orifice (10 mm. in diameter), tube long and of medium width, the transition between the tube and the dilated portion abrupt; limb divided to about half its depth, folded at the junctions of the lobes; lobes rounded at the base with short apical points. *Capsule* longer than the persistent calyx, conical; apex blunt.

The anthers burst as the corolla expands and are then approximately level with the stigma. They maintain this position in the fully open flower and are level with the orifice of the corolla.

TYPE XXXVII.

Type XXXVIII. Plants somewhat late and tall ; height 134 cms.; internodes short giving the plant a somewhat bushy appearance, several large leaves near the ground. *Leaves* sessile, inserted at an angle of 60°, the upper portions of the leaves tend to become horizontal, amplexicaul, auriculate, decurrent, elliptical, lamina only narrowed just at the base ; secondary veins arise at an angle of 60° ; apex acute ; margin with regular very small undulations ; surface slightly puckered ; colour light green ; texture thin ; average length 47 cms.; ratio length/breadth 1·8. *Inflorescence leaves* similar to the lower leaves. *Inflorescence* not conspicuous and not much raised. *Flowers* very pale pink in colour ; length 45 mm. *Calyx* globular, inflated, about one-quarter the length of the corolla ; teeth moderately long and acute. *Corolla* with a wide orifice (diameter 10 mm.), tube exceedingly broad and the dilated portion very short, the transition between the latter and the tube very abrupt (the shape of the corolla in this type is unique among the Indian tobaccos) ; limb quite entire. *Capsule* longer than the persistent calyx, conical ; apex pointed.

The anthers do not burst in the bud but as the corolla expands, when the anthers are well above the stigma. In the fully open flower the burst anthers are about 5 mm. above the stigma and project from the orifice of the corolla.


TYPE XXXVIII.

Type XXXIX. Plants somewhat late; height 128 cms.; internodes moderately long, no leaves borne on the ground; leaves large and numerous. *Leaves* sessile, inserted at an angle of about 60° and tend to bend over at the apex, amplexicaul, auriculate, decurrent for 2·5 cms. or more, elliptical, lamina much reduced for a short distance above the base; secondary veins arise at an angle of nearly 90°; apex acute; margin with slight regular undulations; surface slightly puckered and raised between the secondary veins; colour light green; texture thin; average length 45 cms.; ratio length/breadth 1·9. *Inflorescence leaves* similar to the lower leaves but narrower and not auriculate or decurrent. *Inflorescence* not conspicuous with a few spreading side branches. *Flowers* pink in colour; length 40 mm. *Calyx* somewhat globular, inflated, a little less than half the length of the corolla; teeth short and acute. *Corolla* with a very narrow orifice (diameter 7 mm.) and a broad tube, the transition between the tube and the dilated portion gradual; limb somewhat deeply divided with folds at the junctions of the lobes; lobes rounded and pointed but without an apical point. *Capsule* slightly longer than the persistent calyx, conical; apex pointed.

The anthers burst in the bud when below the stigma. In the fully open flower the empty anthers are level with the stigma and project with the latter beyond the orifice of the corolla.

TYPE XXXIX.

Type XL. Plants very early, short; height 118 cms., lower internodes short, causing a few of the leaves to lie on or near the ground, upper internodes long, the majority of the large leaves being borne at regular intervals up the stem. *Leaves* sessile, inserted at an angle of 60°, amplexicaul, auriculate, decurrent for about 2·5 cms. (the decurrent portion broad), elliptical, lamina slightly narrowed in the basal fifth of the leaf; secondary veins arise at an angle of 60°; apex acute; margin entire; surface flat; a few deep undulations at the base of the leaves; colour bright green; texture medium; average length 42 cms.; ratio length/breadth 2·1. *Inflorescence leaves* similar to the lower leaves but lanceolate in shape. *Inflorescence* raised with several long side branches which are parallel to, but not as long as, the main axis. *Flowers* a deep pink colour which does not fade much; length 45 mm. *Calyx* globular, inflated, about one-third the length of the corolla; teeth moderately long and acute. *Corolla* with an orifice 8 mm. in diameter, and a broad tube, the transition between the tube and the dilated portion gradual; limb divided to about half its depth; lobes rounded at the base with pointed apices, but no apical point. *Capsule* large and stout, shorter than the persistent calyx, conical; apex pointed.

The anthers burst just as the bud expands when they are about 5 mm. above the stigma. In the fully open flower the stigma and empty anthers maintain their relative positions and are approximately level with the orifice of the corolla.

TYPE XL.

TYPE LI. XLIX. L. XLVIII. XLVII. XLI. XLV. XLVI.

FLOWERS AND CAPSULES.

Sub-class 2. All the internodes equal in length and moderately long.

There is great diversity in height in the eleven types belonging to this sub-class, but a wonderful uniformity in leaf shape and structure of the flower. Types XLI, XLIII, XLIV and XLV form a series increasing in height and in size of leaf. In other respects they resemble each other very closely. The flowers are of the same type, but show small differences in the amount of indentation of the corolla limb, length of the apical point, etc. (see Plate XLVIII). Types XLI and XLII are almost indistinguishable from one another, but differ persistently from year to year in the size, colour and texture of their leaves. Type XLVI differs somewhat from this series in the shape of the leaves which are narrowed above the base to a slightly greater extent.

Types XLVIII, XLIX, L, LI resemble each other very closely in the shape of their leaves and the structure of their flowers and capsules. Types L and LI are exceedingly alike, but type L is shorter and its leaves are more vertical and darker in colour than those of type LI.

Type XLVIII is very like LI, but is much shorter and the angle of inset of the leaves is 90° instead of 60°. In type XLIX the leaves are exceedingly vertical. Types XLVIII, XLIX, L and LI form a series as regards height and differ in the angle of insertion of the leaves. Type XLIX is easily distinguished in the field by the light colour of its leaves.

Type XLI. Plants very early, dwarf; height 108 cms.; very bushy plants with short internodes, numerous small leaves and many side branches, no leaves are borne on the ground and the lowest portion of the plant is the narrowest. *Leaves* sessile, inserted at an angle of 60°, very slightly auriculate, amplexicaul and decurrent to a varying amount which may be as much as 2·5 cms., the decurrent portion of the lamina very broad; shape elliptical, lamina very slightly narrowed towards the base; secondary veins arise at an angle of nearly 90°; apex acute; margin with occasional large undulations which are more frequent towards the base of the leaf; surface very slightly puckered; colour blue-green; texture medium; average length of leaf 27 cms.; ratio length to breadth 2·1. *Inflorescence leaves* resemble the lower leaves in every respect but are smaller. *Inflorescence* not conspicuous and not much raised with numerous side branches which surpass the main axis in height and are parallel to it. *Flowers* a very deep pink colour; length 44 mm. *Calyx* globular, less than one-third the length of the corolla; teeth short and obtuse. *Corolla* with an opening 8 mm. in diameter, the transition between the tube and the dilated portion abrupt; limb undivided but with slight indentations between the lobes and very small apical points. *Capsule* slightly longer than the persistent calyx, cylindrical and very narrow; apex blunt.

The anthers burst as the flower expands when they are slightly above the stigma. In the open flower the anthers are above the stigma.

Type XLII. Resembles type XLI in every respect except as regards the leaves. These are smaller (average length 25 cms.; ratio length/breadth 2·3) with a smoother surface and fewer undulations, and are slightly darker than in type XLI. These differences, though slight, are quite distinct and are maintained from year to year.

TYPE XLI.

Type XLIII. Plants very early; height 112 cms. This type resembles types XLI and XLII very closely, but the plants are taller and the leaves larger and fewer in number. *Leaves* sessile, inserted at an angle of 60°, afterwards becoming horizontal, very slightly auriculate, amplexicaul, decurrent to a varying amount, the decurrent portion of the lamina very broad; shape elliptical, the lamina being very slightly narrowed towards the base; secondary veins arise at an angle of nearly 90°; apex acute; margin with occasional large undulations which are more frequent towards the base of the leaf; surface very slightly puckered; colour somewhat dark yellowish green; texture medium; average length of leaf 32 cms.; ratio length/breadth 2·2. *Inflorescence leaves* resemble the lower leaves in every respect, but are smaller. *Inflorescence* not conspicuous and not much raised with numerous side branches which surpass the main axis in height and are parallel to it. *Flowers* resemble those of type XLI in most respects, but the calyx is slightly longer and less globular and the indentations between the lobes of the corolla and also the apical points are more marked. *Capsule* larger than in type XLI and more pointed.

Pollination takes place in the same manner as in type XLI, but the anthers are raised further above the stigma.

TYPE XLIII.

Type XLIV. Plants somewhat early; height 116 cms.; similar in habit to types XLI and XLII, but taller and with larger leaves; internodes moderately long, no leaves lie on the ground. *Leaves* sessile, inserted at an angle of 60°, but tend to become horizontal later, slightly auriculate, amplexicaul and decurrent, the decurrent portion of the lamina is very broad; shape elliptical, lamina slightly narrowed towards the base; secondary veins arise at an angle of nearly 90°; apex obtuse; margin with very occasional slight undulations; surface flat; colour dark yellowish green; texture medium but thinner than in types XLI and XLII; average length 32 cms.; ratio length/breadth 2·2. *Inflorescence leaves* resemble the lower leaves in every respect, but are smaller. *Inflorescence* not conspicuous and not much raised with numerous side shoots which surpass the main axis in height and are parallel to it. *Flowers* pale pink in the bud, the expanded corolla being white; length 44 mm. The flowers resemble those of type XLI, but the calyx is slightly longer and less globular. *Capsule* longer than the persistent calyx, conical; apex somewhat pointed.

The anthers burst in the bud or just as the flower expands when they are slightly above or round the stigma. In the fully open flower they occupy the same position as regards the stigma which is generally covered with pollen.

TYPE XLIV.

Type XLV. Plants somewhat early, tall; height 137 cms.; internodes long; leaves large; the habit of the plants is not so bushy as in types XLI, XLII, XLIII and XLIV. *Leaves* sessile, inserted at an angle of 60°, but tend to become horizontal later, very slightly auriculate, amplexicaul, decurrent to a varying amount, the decurrent portion of the lamina very broad; shape elliptical, lamina slightly narrowed towards the base; secondary veins arise at an angle of nearly 90°; apex acute; margin with occasional very slight undulations; surface flat; colour light green; texture thin; average length of leaf 37 cms.; ratio length/breadth 2·2. *Inflorescence leaves* resemble the lower leaves in every respect, but are smaller. *Inflorescence* not conspicuous, not much raised; side branches fewer in number than in types XLI, XLII and XLIII, equal in length to the main axis and parallel to it. *Flowers* deep pink in the bud; pale pink or white in the expanded flower; length 50 mm. *Calyx* somewhat globular, less than half the length of the corolla; teeth short and obtuse. *Corolla* with an orifice 9 mm. in diameter, the transition between the tube and the dilated portion abrupt; limb quite entire. *Capsule* equal in length to the persistent calyx, conical; apex somewhat pointed.

The anthers burst in the bud when just above the stigma. In the open flower the burst anthers are decidedly above the stigma.

TYPE XLV.

Type XLVI. Plants somewhat early; height 126 cms.; internodes short; leaves very large, none borne on the ground. *Leaves* sessile, inserted at an angle of 45° to 60°, becoming horizontal or even bending downwards later, auriculate, amplexicaul, very decurrent (sometimes as much as 5 cms.), the decurrent portion of the lamina being broad; shape elliptical, the lamina decidedly narrowed in the basal fourth of the leaf; secondary veins arise at an angle of 60°; apex acute; margin with very slight undulations; surface flat; colour light green; texture thin; average length 52 cms.; ratio length/breadth 2·6. *Inflorescence leaves* like the lower leaves but smaller. Inflorescence inconspicuous, not much raised; side branches not very numerous. *Flowers* a very pale pink colour which rapidly fades to white; length about 44 mm. *Calyx* tubular and inflated, about half the length of the corolla; teeth moderately long and acute. *Corolla* with a broad tube; orifice of the corolla 9 mm. in diameter, the transition between the tube and the dilated portion gradual; limb entire, but with deep indentations between the lobes which bear short apical points. *Capsule* slightly longer than the persistent calyx, large, broad at the base, but tapering towards the apex which is blunt.

The anthers are at about the same level as the stigma and burst in the bud. In the fully open flower the anthers and stigma occupy the same relative positions and are level with the orifice of the corolla.

TYPE XLVI.

Type XLVII. Plants somewhat late, not very tall ; height 133 cms. ; internodes moderately long. Leaves borne at regular intervals up the stem, none on the ground. *Leaves* sessile, inserted at an angle of 90° and bend downwards at the tip, slightly auriculate, slightly amplexicaul, decurrent for 2·5 cms., the decurrent portion broad ; shape elliptical, lamina somewhat narrowed for a short distance above the base ; secondary veins arise at an angle of about 90° ; apex acute ; margin very slightly undulate, recurved ; surface slightly puffy or puckered ; colour somewhat light green ; texture medium to thick ; average length 42 cms. ; ratio length/breadth 1·9. *Inflorescence leaves* similar to the lower leaves but with more acute apices. *Inflorescence* more conspicuous and with more flowers than in types L and LI ; side branches level and parallel with the main axis. *Flowers* very pale pink in colour ; length 45 mm. *Calyx* less globular than in types L, LI and XLVIII, inflated, about one-third the length of the corolla ; teeth short and acute. *Corolla* with a wide orifice 10 mm. in diameter and an exceedingly broad tube, the transition between the tube and the dilated portion abrupt ; limb entire but indented and folded at the junctions between the lobes ; apical points very short. *Capsule* equal in length to the persistent calyx, conical ; apex pointed.

The anthers burst when just around or just above the stigma before the corolla expands. In the open flower the burst anthers are either just above the stigma or about 5 mm. above it ; in either case they are approximately level with the orifice of the corolla.

This type resembles type XLVIII in many respects such as habit, position of the leaves, etc. It differs, however, in some particulars such as the texture, colour of the leaves, and the indentation of the corolla lobes.

TYPE XLVII.

Type XLVIII. Plants somewhat late ; height 114 cms. ; internodes moderately long. Leaves borne at regular intervals up the stem, none on the ground. *Leaves* sessile, inserted at an angle of 90° and bend downwards at the tip, slightly amplexicaul and auriculate, decurrent for about 5 cms., the decurrent portion broad ; shape elliptical, lamina somewhat narrowed above the base but for a lesser distance than in type LI ; secondary veins arise at an angle of about 90° ; apex acute ; margin very slightly undulate, recurved ; surface slightly puffy or puckered ; colour dark blue-green ; texture thin ; average length 38 cms. ; ratio length/breadth 1·9. *Inflorescence leaves* similar to the lower leaves, but apices more acute and base more undulate. *Inflorescence* more conspicuous ; flowers much more numerous than in type LI ; side branches spreading and shorter than the main axis. *Flowers* very pale pink in colour, long ; length about 50 mm. *Calyx* globular and inflated, less than one-third the length of the corolla ; teeth short and acute. *Corolla* with a wide orifice 10 mm. in diameter and a broad tube, the transition between the tube and the dilated portion very abrupt ; limb entire but somewhat deeply indented and folded at the junctions of the lobes ; apical points short. *Capsule* equal in length to the persistent calyx, conical ; apex pointed.

The anthers burst when just round or just above the stigma before the corolla expands. In the open flower the burst anthers are slightly above the stigma and are well below the orifice of the corolla.

TYPE XLVIII.

Type XLIX. Plants somewhat late, tall ; height 160 cms. ; internodes long, leaves borne at regular intervals up the stem, none on the ground. The leaves are vertical, giving the plants a very characteristic appearance. *Leaves* sessile, inserted at an angle of 45° or less, auriculate, amplexicaul, decurrent for 7 cms., the decurrent portion is broad at the top and then suddenly becomes narrow ; shape elliptical, lamina only very slightly narrowed at the base ; secondary veins arise at an angle of about 90° ; apex acute ; margin very slightly undulate ; surface practically flat ; colour light green ; texture thin ; average length 49 cms. ; ratio length/breadth 2·0. *Inflorescence leaves* similar to the lower leaves, but with more acute apices. *Inflorescence* with few flowers, and few side branches which are borne at the top of the stem. *Flowers* very pale pink in colour, short (length 40 mm.). *Calyx* globular and inflated, about one-third the length of the corolla ; teeth short and somewhat obtuse. *Corolla* with a wide orifice (11 to 12 mm. in diameter) and a very broad tube, the transition between the tube and the dilated portion very abrupt ; limb entire but indented and slightly folded at the junction of the lobes ; apical points short. *Capsule* slightly longer than the persistent calyx, conical ; apex acute.

The anthers are late in shedding their pollen and only burst as the flower expands when they are approximately level with the stigma. The burst anthers and stigma retain their relative positions in the fully open flower and are level with the orifice of the corolla.

TYPE XLIX.

Type L. Plants somewhat late, tall; height 163 cms.; internodes long; leaves borne at regular intervals up the stem, none on the ground; inflorescence not very conspicuous. *Leaves* sessile, inserted at an angle of 45° but tend to become somewhat horizontal later, slightly amplexicaul, auriculate, decurrent for 5 cms. or more, the decurrent portion broad; shape elliptical, lamina somewhat narrowed in the basal third of the leaf; secondary veins arise at an angle of about 90°; apex acute; margin very slightly undulate and recurved; surface slightly puffy or puckered; colour bluish green, but not quite as dark as in type LI; texture thin; average length 42 cms.; ratio length/breadth 1·8. *Inflorescence leaves* similar to the lower leaves, but with more acute apices. *Inflorescence* with few flowers and few side branches. *Flowers* very pale pink in colour; length 45 mm. *Calyx* globular and inflated, less than one-third the length of the corolla; teeth short and acute. *Corolla* with a wide orifice 11 mm. in diameter and a very broad tube, the transition between the tube and the dilated portion very abrupt; limb entire but indented and somewhat folded at the junctions of the lobes; apical points very short. *Capsule* longer than the persistent calyx, conical; apex pointed.

In the bud, before the corolla expands, the anthers are found just above the stigma and burst while in this position before the bud opens. In the fully open flower the burst anthers are about 5 cms. above the stigma and project beyond the orifice of the corolla.

This type resembles very closely type LI, but differs from the latter in height and in the position and colour of its leaves, which are more vertical and less dark in colour. Types LI, L and XLVIII form a series in which the height diminishes and the position of the leaves becomes more horizontal.

TYPE L.

Type LI. Plants somewhat late, very tall ; height 178 cms. ; internodes long, leaves borne at regular intervals up the stem. none on the ground ; inflorescence not very conspicuous. *Leaves* sessile, inserted at an angle of 60°, slightly amplexicaul and auriculate, decurrent for 5 cms. or more, the decurrent portion broad ; shape elliptical, lamina somewhat narrowed in the basal third of the leaf ; secondary veins arise at an angle of about 90° ; apex acute ; margin very slightly undulate and recurved ; surface slightly puffy or puckered ; colour dark blue-green ; texture very thin ; average length 43 cms. ; ratio length/breadth 1·8. *Inflorescence leaves* similar to the lower leaves, but with more acute apices. *Inflorescence* with few flowers ; the side branches which are borne at the top of the stem are few in number and almost level with the main axis and parallel to it. *Flowers* very pale pink in colour, fading to white ; length about 45 mm. *Calyx* globular, inflated, less than one-third the length of the corolla ; teeth short and acute. *Corolla* with a wide orifice 11 mm. in diameter and a very broad tube, the transition between the tube and the dilated portion very abrupt ; limb entire but indented and somewhat folded at the junctions of the lobes ; apical points very short. *Capsule* longer than the persistent calyx, conical ; apex pointed.

In the bud before the corolla expands the anthers are found just above the stigma and burst while in this position before the bud opens. In the fully open flower the burst anthers are about 5 mm. above the stigma and project from the orifice of the corolla.

This type has an exceedingly good texture, the leaves are much thinner than in the ordinary Indian tobaccos. It has the great disadvantage, however, that the leaves are much exposed to the wind and do not protect each other as in the more bushy types. For this reason they are often badly torn before they ripen.

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August 9th, 1909.

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Memoirs of the Department of Agriculture in India

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No. 1. ON TWO VARIETIES OF SANN CROTALARIA JUNCEA, L

BY

ALBERT HOWARD, M.A., A.R.C.S., F.L.S

Imperial Economic Botanist

AND

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Associate and former Fellow of Newnham College, Cambridge

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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One of the most important and most widely distributed annual fibre-yielding plants cultivated in India is *Sann* or *Sann-hemp—Crotalaria juncea*, L. It is grown in all the Provinces including Burma, but appears to be most widely cultivated in Madras, the United Provinces and in the Central Provinces. The extent to which it is cultivated as a fibre plant, for green manuring and for fodder purposes in all the Provinces of British India, except Bengal,[1] will be evident from the following extract from the *Proceedings of the Board of Agriculture in India* of 1909, pages 56 and 57, which gives the latest information on the subject.

"*Crotalaria juncea.*—The fibre of this crop does not compete with jute as does that of *Hibiscus cannabinus*, but in market value it is superior to both. *Sann*-hemp can best be grown in districts of moderate rainfall, and, therefore, does not compete with rice. It is, in some parts of India, frequently grown as a green manure crop before rice, and in others as a second crop in the same year after early rice for fibre. This rotation is advantageous, because *Sann* is a leguminous crop.

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[1] Statistics of the area and production of *Sann* in Bengal are not at present available.

"The total acreage under the crop in the Bombay Presidency in 1906-07 was 23,700 acres, and in 1907-08, 25,470 acres. It is chiefly grown as a *kharif* crop for fibre, but also to a considerable extent as a green manure crop. In the Thana District, it is grown as a *rabi* crop in succession to early rice for fibre, which is used in making twine for nets by the fishermen.

"The returns for Madras give a total of over 300,000 acres; but it is known that only a very small proportion of this—a few thousand acres—is grown for fibre. It is most extensively cultivated for fibre in the Northern Circars, chiefly in the Amalapuram and Narsapur Taluks of the Godavari and Krishna Districts. In the rest of the Presidency with the exception of the Tinnevelly District, where some fibre is manufactured into extremely durable gunny bags, the cultivation of the crop is confined to the production of fodder.

"In Eastern Bengal and Assam this crop is largely grown in the Serajganj sub-division of the District of Pabna, where the estimated area is 33,900 acres. Generally it is grown in Serajganj on land which bears a jute crop in the same year. The area in Chittagong, where it is also grown as a *rabi* crop, decreased from 7,900 acres in 1906-07 to 1,600 acres in 1907-08. The total estimated area in Eastern Bengal and Assam is about 42,000 acres, and the estimated export of the fibre is 30,000 maunds. In this Province jute is much more important, but it is possible that the cultivation of *Sann*-hemp can be somewhat extended with profit, though as the water-supply for retting is limited in February and March, the months of its cutting, this would only be along the banks of rivers. In the Serajganj sub-division it is only grown for fibre quite close to water.

"A note by Mr. Clouston, the Deputy Director of Agriculture in the Central Provinces, on the cultivation of fibre plants in the Central Provinces, has been published in the *Agricultural Journal of India* (April 1908). The total area under *Sann* in the Central Provinces was 55,400 acres in 1907, which increased in 1908 to 85,044 acres. In Berar in 1907 the acreage was 32,360 and in 1908, 35,484. It is always grown as a pure crop and is cultivated

for its fibre chiefly, while the seed is a valued cattle food. It is generally believed that only one variety of *Sann* is grown throughout the Central Provinces and Berar. Retting costs a good deal. A suitable cheap machine to extract the fibre might be advantageous in extending the cultivation. The area in the Central Provinces has been nearly doubled during the last ten years. *Sann* cultivation is so profitable that the crop has been largely substituted for wheat. The cultivators understand that this crop is a hardy one and improves the condition of the land. It is grown to a small extent as a green manure crop, particularly for irrigated wheat and sugarcane. In the cotton tracts no extension of this crop can be expected, as cotton pays better. In the rice tracts, *Sann* could probably be profitably grown on much of the land which is planted with other second crops. The total quantity of *Sann*-hemp exported from the Province and the value of the same from 1904 to 1906 are shown below :—

Year.	Maunds.	Value.
		Rs.
1904-05	226,751	12,18,783
1905-06	201,402	10,82,534
1906-07	168,096	9,03,513
1907-08	271,727	14,60,532

"In the Punjab there were 57,000 acres under *Sann*-hemp in 1906 and 52,400 acres in 1908; the sub-montane tracts showed the greatest area. Very little is grown in the south-west of the Province. Throughout the Punjab, the crop is usually sown in very small plots, and very little is marketed. The crop is sown almost solely for fibre, but in the Hoshiarpur District, it is estimated that one-tenth of the crop was grown for green manuring. The practice of green manuring with *Sann* is, however, rare at

present. The retting and cleaning of the fibre are regarded as very tedious and troublesome processes. Having regard to these troubles, the crop is considered to be less remunerative than some other crops. The imports of *Sann*-hemp fibre into the Punjab in 1906-07 were 15,382 maunds and in 1907-08, 20,984 maunds, almost entirely from the United Provinces. The exports amounted to only 4,078 maunds in 1906-07 and 2,584 maunds in 1907-08.

"The returns of the United Provinces show an area in 1906-07 of 133,000 acres of hemp, which include both *Hibiscus cannabinus* and *Sann*-hemp: and in 1907-08 of 158,000 acres. Practically the whole of this area is devoted to *Sann*-hemp. It is grown for fibre and almost universally as a border crop with *kharif* crops, the produce being worked up by cultivators into ropes for home use. The export is, therefore, a small part of the produce. The trade returns of the United Provinces for 1906-07 show practically no imports of the hemp, but exports aggregating 400,000 maunds, valued at 22 lakhs of rupees, and in 1907-08 of 409,800 maunds, valued at Rs. 26,17,000; most of this is *Sann*-hemp. There is a steady trade to Calcutta and a very fluctuating trade to Bombay. The crop is a well-recognized feature of the local agriculture, and the trade in fibre is an organized one. The area generally responds to the prices offered.

"This crop does well in the Tavoy District of Tenasserim. It is grown there after paddy. The estimated area is about 400 acres in Lower Burma. The fibre is used for fishing nets. It is very doubtful whether there will be any great development of this crop, unless the Department of Agriculture, Burma, succeeds in introducing it for green manuring."

The export trade in *Sann*-hemp fibre appears to be most important in the United Provinces, the amount exported in 1907-08 being valued at twenty-six lakhs of rupees.

Considerable attention appears to have been paid to *Sann*-hemp in India towards the close of the eighteenth and the beginning of the nineteenth century by several writers, including Roxburgh and Wisset, and the earlier information on the subject is

summed up by Royle.[1] Watt [2] has brought the subject up-to-date and has included in his account of *Crotalaria juncea*, the recent work done at the Calcutta Botanical Gardens. Royle seems to have been the first to raise the question of the existence of more than one fibre-yielding species of *Crotalaria* in cultivation in India. It appears that specimens of cordage of excellent quality, and said to be made of Jubbulpore hemp, were sent to the 1851 Exhibition by Messrs. Harton & Co., rope-makers of Calcutta. Samples of this fibre, obtained by Royle in 1853, proved to be equal if not superior to Russian hemp and were valued at £30 to £35 a ton. He considered the plant which gave rise to this fibre was *Crotalaria tenuifolia*, R. This determination seems to have been made on the authority of Falconer,[3] to whom a specimen was referred. Wight and Arnott,[4] however, regarded *C. tenuifolia* as a variety of *C. juncea*, the plant affording the well-known "*Sann*-hemp" of commerce. That Falconer's diagnosis was incorrect will be evident from Roxburgh's description of *C. tenuifolia*,[5] which is as follows :—

"*C. tenuifolia* R. Perennial, ramous, straight-furrowed, hoary. *Leaves* linear, sericeous underneath. *Stipules* minute, subulate. *Racemes* terminal. *Legumes* sessile, clavate, many-seeded.

"A native of Coromandel. In the Botanic Garden it is perennial, growing to the height of nine feet, with numerous, slender, furrowed, straight branches, which are again more ramous at the top ; during the cool season each twig ends in a long raceme of large yellow flowers and the seed ripens in two months."

Jubbulpore hemp, on the other hand, is a tall straight annual with linear lanceolate leaves, while *C. tenuifolia* R. is described by Roxburgh as a branched perennial with linear leaves and a native of Coromandel.

Nothing seems to have been done in India on the botany of the plants yielding *Sann*-hemp until 1902 when the source of the

[1] Royle, *The Fibrous Plants of India*, London, 1855, p. 271.

[2] Watt, *The Commercial Products of India*, London, 19.8, p. 430.

[3] *Proceedings of the Agri-Horticultural Society of India*, April, 1851.

[4] Wight and Arnott, *Prod.* i, 185.

[5] Roxburgh, *Flora Indica*, Calcutta, 1874, p. 546.

Sann-hemp of commerce was taken up by the Calcutta Botanical Gardens. Watt[1] sums up the results of these experiments as follows :—"Recent experiments conducted at the Royal Botanic Gardens, Calcutta, support the belief that all the trade qualities represent seasons of growth or methods of separation of fibre, and not botanical forms." Further, Watt states : "It would seem from the Calcutta experiments that all the forms hitherto grown from seed procured from such remote localities as Vizagapatam, Jubbulpore, Pillibhit, etc., have resulted in plants of varying stature, size of flower, etc., but in no structural departures that could justify even varietal positions being assigned to them." Thus it would appear proved that there is only one species of *Sann*-hemp widely cultivated in India, namely, *C. juncea*, and that Royle's view that Jubbulpore hemp is *C. tenuifolia* is incorrect.

From the *kharif* season of 1906 to the present time many sowings of *Sann*-hemp from various parts of the Central Provinces, including Jubbulpore, have been made by us at Púsa. Some of these have been on a large scale either for green manuring, for fibre or for seed. Observations have also been made in the *Sann*-hemp fields of the Central Provinces on the botanical composition of the crop.

The first sample of Jubbulpore hemp was sown in the *kharif* of 1906, and single plants of this were selected for seed for the following year. In 1907 and 1908 the sowings were repeated, and from the 1908 harvest single plants from each of the plots were selected for carrying on the cultures in 1909. Thus Jubbulpore hemp has been grown for four seasons, and from Púsa grown seed for three seasons. No change has been observed in the behaviour of the cultures—either in botanical characters, in habit of growth, length of stem or in earliness. Further, all the pure line cultures have shown themselves to be identical in all respects, and Jubbulpore hemp seems to contain only one type.

Consignments of *Sann*-hemp seed were obtained from the Agricultural Department of the Central Provinces in 1906 and again in 1909, and the produce of these was compared with the cultures of

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[1] Watt, l. c.

Jubbulpore hemp grown at Púsa. No differences were observed, and it appeared likely that only one variety of this crop is generally cultivated in the Central Provinces.

In 1908, our attention was arrested by the marked difference in appearance between the seedlings on a field sown with Central Provinces *Sann*-hemp and those in a field sown with the local *Sann*-hemp. A portion of each was allowed to seed and further differences were noted in the ripe plants. Accordingly the seed of a large number of single plants of each of these fields was saved and sown separately in 1909 side by side and under uniform conditions. Observations were also made on a field divided into three parallel strips and sown with local seed, seed from the third generation at Púsa-grown Jubbulpore hemp and with seed freshly imported from Hoshangábád. No differences were observed between the Púsa-grown Jubbulpore hemp and that from Hoshangábád. These proved identical.

There were marked differences, however, between the local *Sann*-hemp and that from the Central Provinces, and these differences could be easily traced from the seed to the mature plant.

The seeds of the two varieties are quite distinct. The seeds of the local *Sann*-hemp are small, shiny and quite black ; those of the Jubbulpore hemp are much larger, duller and bluish black or greyish. The differences in time of germination are equally marked. The larger seeds of the Jubbulpore variety germinate with remarkable rapidity, and the seedlings appear above ground from 12 to 24 hours earlier than those of the local variety when both are sown at the same time and under equal conditions. The start gained by the Jubbulpore variety is never lost throughout the whole of the after-development of the plant and the Central Provinces variety is always larger, taller, and earlier than the local. In addition to the speed of germination and of subsequent growth the characters of the seedlings of the two varieties are quite distinct. The average length of the seed-leaves of the local seedlings is 22 mm., that of the Jubbulpore variety 30 mm. On account of this difference the appearance of the two sets of seedlings is very different. Apart from the size of the seed-leaves, there are other distinctions. The

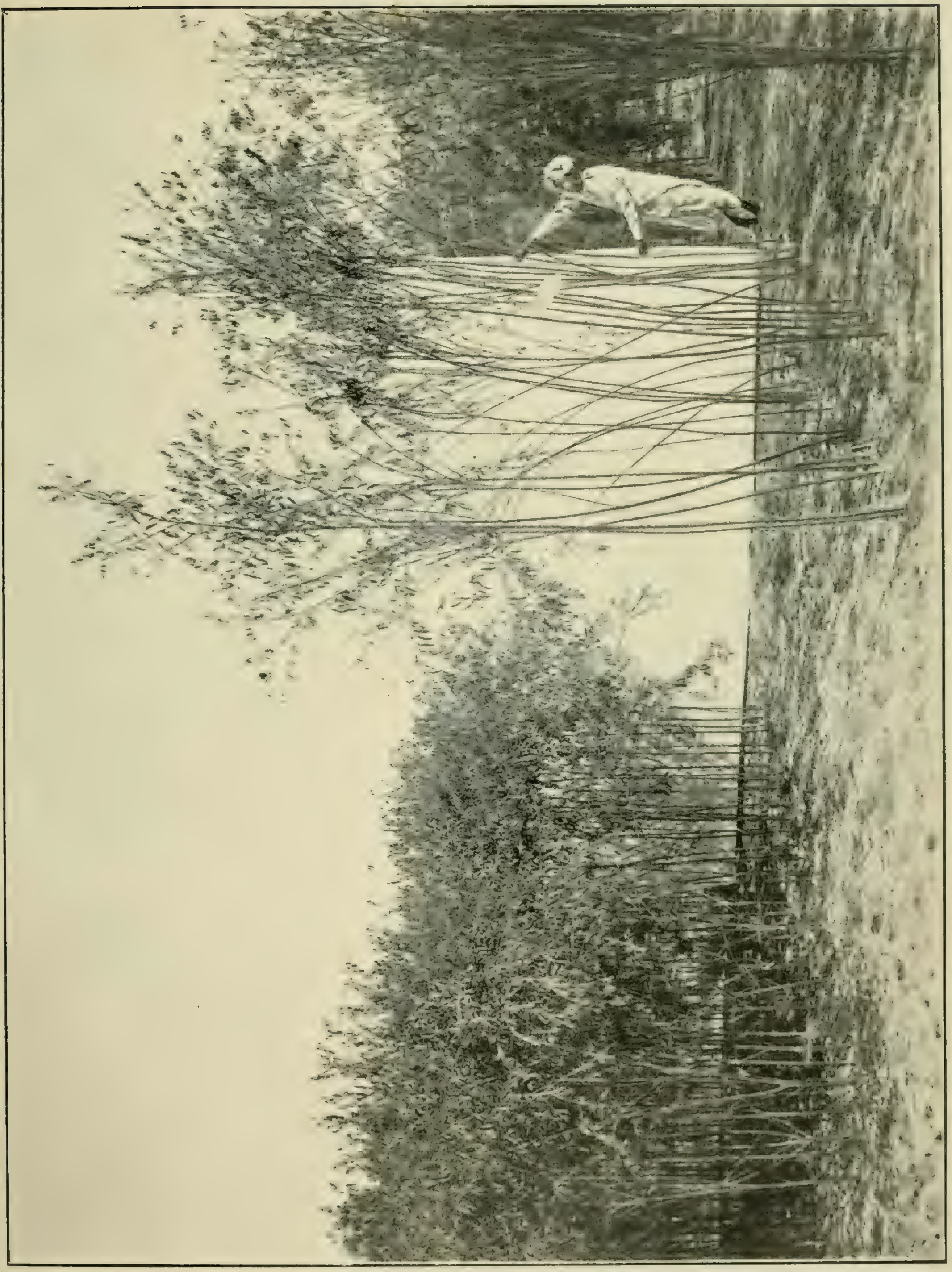
under-surface of the cotyledonary leaves of the local variety is reddish and this reddening is also to be seen on the stems. Further, both the under-surface of these leaves and the stems are hairy. In the case of the Jubbulpore variety the under-surface of the first leaves and the stems are quite green and glabrous. Seven weeks after sowing, the local plants measured on the average 114 cms. in height, while the Jubbulpore plants were 157 cms. on the average. After the seedling distinctions, it is in the branching of the two varieties that the greatest differences are to be seen. The local variety generally branches about four feet above the ground; the branches are long and spreading with secondary and often tertiary arms, the whole forming a dense canopy. The Jubbulpore variety branches about eight feet from the ground, throwing off a few erect parallel shoots with little or no secondary branching and no canopy is formed. The local variety is late and yields abundance of flowers and seed, while the Jubbulpore variety flowers much earlier and forms but few seeds.

The above differences are summed up in the following table :—

Local variety.	Jubbulpore variety.
1. *Seed.* Small, shiny, black.	Large, dull black or greyish.
2. *Seedlings.* Germination slow, seedlings small with reddish downy cotyledonary leaves and stems.	Germination rapid. Seedlings large with green glabrous cotyledonary leaves and stems.
3. *Plants.* Short, late maturing with many-flowered spreading branches beginning at a point about four feet from the ground.	Tall, early maturing with a few short sparsely flowered parallel branches beginning at a point about eight feet from the ground.

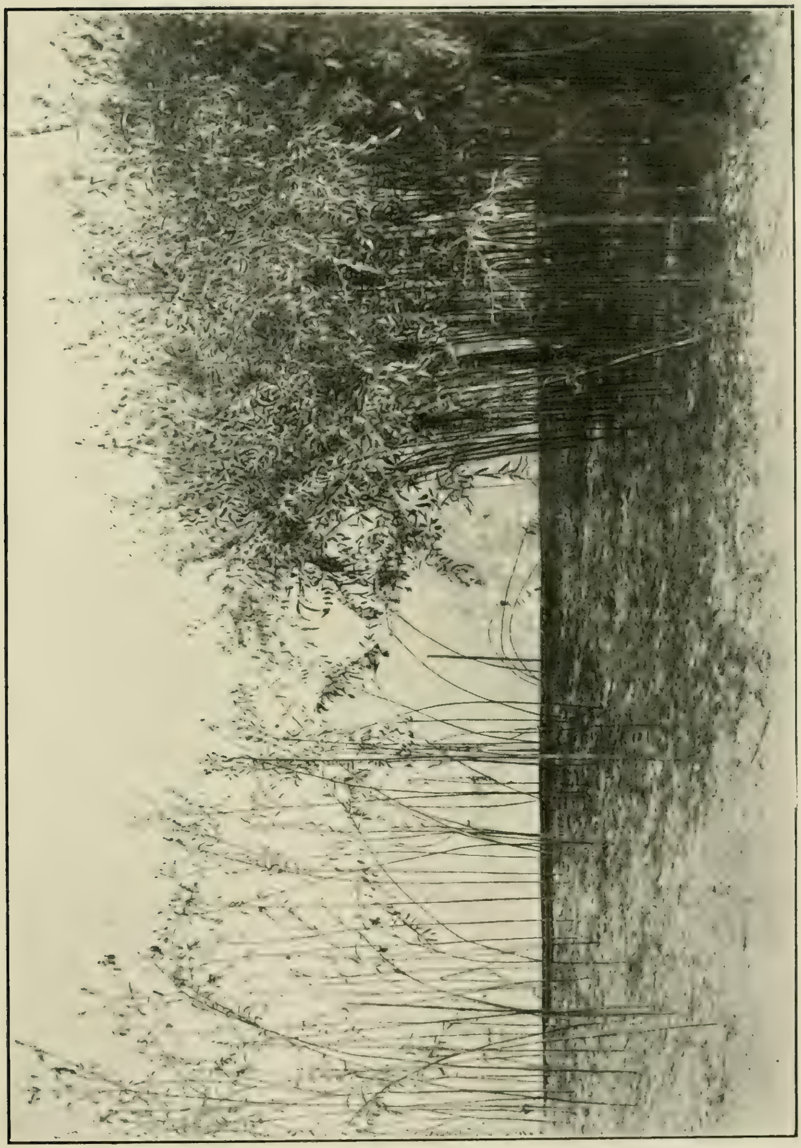
The general habit differences at flowering time can be seen in Plate I. The rows on the right are pure line cultures of Jubbulpore hemp. Those on the left are similar cultures of the local variety. In Plate II the same varieties are again shown, but in this case the local variety is on the right. The much shorter growth of both varieties is due in this case to late sowing. In all cases but poor development is obtained with *Sann*-hemp when sowing is deferred till the middle of the monsoon. To obtain the best results

PLATE I.



Pure line cultures of Local and Jubbulpore Sann at Pusa.

PLATE II.



THE DWARFING EFFECT OF LATE SOWING ON SANN.

The left-hand plot is Jubbulpore *Sann*, the right-hand plot the local variety.

both for green manure and fibre, it is necessary to sow *Sann*-hemp at Púsa either on the first monsoon showers early in June or preferably on the *chota barsat* showers in the second half of May. Late sowing unfavourably affects the Jubbulpore variety to a much greater extent than the local. A fair crop of the local variety is obtained even in late sowings.

There is no doubt that there are at least two absolutely distinct varieties of *Sann*-hemp cultivated in India, and that the differences given above are inherent in the varieties. The following excellent description of *Crotalaria juncea* given by Roxburgh in *Flora Indica* (p. 545), applies to both varieties :—

"*Stem* annual, straight, from four to eight feet high, or even more, striated from the insertion of the leaves, a little downy, towards the top branchy, and, when the plant stands single, more so. *Leaves* scattered, short-petioled, lanceolate, obtuse, with a small bristle-like point ; both sides covered with soft, silver-coloured hairs, from two to six inches long, and from half an inch to one and-a-half broad. *Stipules* subulate, small. *Racemes* terminal, single. *Bractes* oval, one-flowered. *Flowers* numerous, papilionaceous, large, of a beautiful bright yellow. *Calyx bilabiate ;* the *upper lip* two-cleft : the *under* one three-parted in the middle, and there gaping ; at the apex the segments are united. *Banner* obtuse. erect. *Wings* oblong, obtuse. *Keel* much pointed, slightly twisted at the apex and closely shut. *Filaments*, their lower half united into one body, with a fissure down the upper side, which has a circular gape at the base ; extremities free, and alternately shorter. *Anthers* on the shorter filaments linear, on the longer ovate, and two lobed. *Legumes* sessile, club-shaped, downy, from one to two inches long. *Seeds* numerous, kidney-formed."

The occurrence of two sorts of stamens in the flowers of this species was observed by Roxburgh who describes them as follows :—

"There is something very interesting in those two sorts of stamens. If a flower is opened some time before the natural time of its expanding, which must be just before any of the anthers

burst, the filaments of the subulate set will then be found considerably longer than those of the round set, and the stigma will then be about the same height: these long anthers come to maturity long before the round ones, and about the time the stigma is among them; but the style continues to grow longer, by which means the bearded stigma pushes on with it much of the pollen from the long anthers whose filaments do not lengthen any more: but those of the round ones now begin to lengthen, pushing their anthers considerably beyond the apices of the linear set, and even with the stigma; by this economy they come in contact with it before or about the time of their maturity. These changes I have found most conspicuous in *Crotalaria juncea* and *pentaphylla*, whose flowers are very large, every part being easily seen with the naked eye."

The fact that the subulate stamens shed their pollen in the bud all round the style and stigma combined with the closely shut and twisted keel would appear to greatly favour self-pollination in this species and to render natural crossing rare. If this supposition is borne out by further observation on the behaviour of the produce of pure lines of both varieties grown next to next and natural crossing is found to be exceedingly rare, then it is likely that few types of this species will be found in cultivation. The absence of crossing would also explain the remarkable purity observed in the crop as grown in the Central Provinces. No evidence of natural crossing was observed in the pure lines of both varieties grown at Púsa in 1909.

The two varieties have been compared at Púsa for green manuring purposes. The rapid germination and growth of the Jubbulpore *Sann* are great advantages over the local variety in years of short rainfall, or when it is essential to establish the crop on the early pre-monsoon showers. This rapid growth also prevents the early growth of weeds. At a much later period of growth and after the green manuring stage these advantages to a great extent disappear and are even reversed. The branching of the local variety before flowering time forms a dense canopy under which weeds are killed out, while the more erect habit of the Jubbulpore

variety enables a bottom growth of weeds to gradually become established unless the hemp is very thickly sown. In 1909, weighments were made of the green crop 53 days after sowing, just before being ploughed in for green manure. In appearance the plots seemed very different, and it was expected the weight of the taller Jubbulpore variety would be much the greater. Actual weighments, however, showed that the difference was very slight. The local variety gave 7 maunds 15 seers per 2,000 sq. feet, the Jubbulpore variety 7 maunds 35 seers, an increase of only 40 pounds. The stubble of the local variety was more weedy than that of the Jubbulpore hemp, but, as has been stated above, this difference is reversed if the plants are allowed to grow for fibre and seed. As far as green manuring is concerned, the advantage is with the Jubbulpore variety, especially if the sowings have to be made early. There is one possible disadvantage, however. The variety from the Central Provinces produces but a poor crop of seed in Bihár, and it remains to be proved whether it would be found cheaper to import fresh seed every year and to use the land, which would otherwise have to carry the crop for seed, for the growth of a *rabi* crop.

The great advantage of *Sann*-hemp as a green manure in improving the quality and productiveness of the soil of the alluvium, although often referred to, does not appear to be fully realised and sufficiently widely adopted in practice. This appears to be due to the manner in which the crop is grown and ploughed into the soil. It often happens that a difficulty is experienced in getting the crop rotted and thoroughly incorporated into the soil before the cessation of the monsoon leading to great damage to the succeeding *rabi* crop through white-ants and through a too open texture caused by the undecomposed stems. These objections are easily overcome by a little care and forethought. To be successful as a green manure and to give time for thorough decomposition and subsequent incorporation of the crop, it should be sown in a previously well prepared and well aerated seed bed preferably on the showers of May or not later than the earliest showers of June. The risk of withering is small as the tap root grows so rapidly that

it quickly reaches the lower soil moisture. By the end of the first week in July the crop can be ploughed in, and before the end of September it will have disappeared entirely. July 15th is the very latest safe date for ploughing in at Púsa, and it is preferable not to delay the ploughing in beyond July 7th. The effect of a successful green manuring is extraordinary. The texture and colour of the soil are altered, heavy lands become easily workable and readily yield a good tilth. The effect on the next few crops is wonderful both in luxuriance and also in rapidity of growth. On tobacco, the land for which is left fallow in the monsoon, the effect is greater than that of a heavy dressing of farm yard manure. In Plate III are shown two plots, the left green manured with *Sann*, the right with old tobacco leaves and stems. The photograph was taken on November 10th, and both plots were transplanted on September 20th. The increased growth of the *Sann* plot is extraordinary, and there seems no reason why this cheap manure should not be much more extensively employed in tobacco-growing in Bihár.

Besides the advantage in rapid growth the *Sann* plots of tobacco at Púsa in 1909 gave a much greater yield per acre than the plots manured with cattle dung, rape cake or old tobacco stems. Further, the green manure plots ripened off earliest of all, and the texture and colour of the cured product were not unfavourably affected by the manurial treatment. Grown after *Sann* it is possible to raise in Bihár large crops of tobacco which ripen off evenly in the second half of December. This admits of the curing being carried out in January before the hot dry west winds set in.

With regard to the relative value of both varieties for fibre in Bihar, it is too early to venture a final opinion. The tall straight unbranched habit of the Jubbulpore hemp is, however, an obvious advantage for fibre purposes over the local variety. A sample of the Jubbulpore plant was submitted to Mr. R. S. Finlow, the Fibre Expert to Eastern Bengal and Assam, who has also examined single plants of both varieties. His report is given below :—

"A comparative examination of Jubbulpore hemp, grown in the Botanical area at Púsa, and ordinary *Sann*-hemp,

PLATE III.

THE EFFECT OF GREEN-MANURING WITH SANN ON TOBACCO.

The plot on the left was green-manured with *Sann*, the plot on the right with old Tobacco leaves and stems.

obtained from the neighbourhood of Púsa, gave the following results :——

	Jubbulpore Hemp.	Local Hemp.
Less on hydrolysis (1 hour in 1% potash) ...	9·75%	13·85%
Cellulose	79·60%	74·80%
Average length of ultimate fibres ...	5·3 mm.	3·98 mm.

These figures, which require further confirmation from samples produced under more nearly identical conditions, indicate a considerable superiority of Jubbulpore hemp over local *Sann*, both from the point of view of strength and of durability. They are supported by the fact that, on being tested, the Jubbulpore hemp showed markedly greater tensile strength than local *Sann*."

The occurrence of two such distinct varieties of *Sann*-hemp in India as those described above shows the desirability of conducting a survey of the crop grown in the various Provinces of India. Accordingly, steps have been taken to collect and grow at Púsa samples of this crop from all the typical tracts in which its cultivation is of importance. Possibly other varieties will be found in addition to the two described in the present paper.

PUSA,

November 13*th*, 1909.

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Memoirs of the Department of Agriculture in India

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No. I. THE EXPERIMENTS OF 1907-08 AND 1908-09

BY

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DIEU ET MON DROIT

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PREFACE.

The experiments described in the present paper have arisen from some preliminary trials with Muzaffarnagar white, made at Púsa, Muzaffarnagar and Lyallpur in 1907. Since that time they have been considerably extended, and now embrace ten stations and four very different classes of wheat. In addition, a large amount of other work on the influence of the environment on quality is being conducted in the Botanical areas at Púsa and Cawnpore.

We desire to take this opportunity of expressing our indebtedness to several officers of the Indian Agricultural Department for their valuable co-operation in the conduct of this work. For facilities at Dumraon and Bankipore we are indebted to Mr. F. Smith, B.Sc., Deputy Director of Agriculture, Bengal; Mr. B. C. Burt, B.Sc., and Dr. Parr, the Deputy Directors of Agriculture of the United Provinces have assisted us at Orai and Aligarh respectively. At Meerut, Babu Jugannath Pershad was good enough to give us all facilities on his farm. Mr. Mahomed Hadi, M.R.A.C., has kindly placed the resources of the Partabgarh Experiment Station at our disposal while at Lyallpur, Messrs. W. Roberts, B.Sc., and H. A. Corbin, B.Sc., have been good enough to assist in the work. During the present year, Mr. G. Evans, B.A., Deputy Director of Agriculture of the Central Provinces, has afforded us facilities at Hoshangabad in the Narbada Valley.

We are indebted to Dr. J. W. Leather, Imperial Agricultural Chemist, for a large number of nitrogen determinations.

In the milling and baking aspect of the subject we have been fortunate enough to secure the invaluable assistance of Mr. A. E. Humphries, formerly President of the National Association of British and Irish Millers and a well-known authority on these questions.

ALBERT HOWARD.
H. M. LEAKE.
GABRIELLE L. C. HOWARD.

CAWNPORE,
December 18th, 1909.

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THE INFLUENCE OF THE ENVIRONMENT ON THE MILLING AND BAKING QUALITIES OF WHEAT IN INDIA.

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I. Introduction.

The question of the effect of environment on the quality of wheat is of the greatest importance from several points of view. Not only does it affect the question of seed distribution and the introduction of new varieties, but it is also of vital interest to the breeder. It has long been a vexed question as to how far excellence of quality in plant products is determined by environment, and how far it can be considered as characteristic of the race. To the plant-breeder, therefore, who wishes to combine in one race excellence on various points a knowledge of the exact part played by hereditary influence and by environment in producing such qualities becomes essential.

Before considering the work of former observers on the subject it will be best to consider firstly what are the characters of the wheat grain which may be affected by change in environment; and secondly the economic significance of such changes.

The characters of the wheat grain which may be affected by change in environment are the following:—

1. *Colour.*—It has often been stated that certain types of soil will transform a white wheat into a red wheat. This subject has been dealt with at length in a former paper,[1] when it was shown that there is no evidence that such a change has ever taken place, except as the result of natural cross-fertilization.

2. *Size and Weight of the Grain.*—The size and absolute weight of the grain vary considerably both in different localities and also

[1] Howard and Howard, *Memoirs of the Department of Agriculture in India (Botanical Series)*, Vol. II, No. 7, 1909.

in the same locality in different seasons. This character, although affecting the yield, cannot be regarded as a criterion of quality.[1]

3. *Composition.*—Much of the work on the subject of the effect of environment on the characters of the wheat grain has been concerned with the effect of change of environment on the nitrogen content of the grain—the nitrogen content being taken as the most convenient indication of the strength of a wheat. Unfortunately although, *as a rule*, the higher the nitrogen content the stronger the flour, nevertheless there are exceptions, some wheats high in nitrogen giving very weak flours.[2] The total nitrogen content is, therefore, not nearly so reliable a test of strength as that obtained by milling and baking the sample. Moreover the quality of a wheat does not depend entirely on the strength of the flour but on many other characters which go to form what is known as quality. Although a great deal of work has been done on the chemical composition of wheat and of wheat flour, yet no accurate relation has hitherto been found between the chemical composition and the bread-making value of wheat. Wood's[3] researches at Cambridge seem to indicate that the physical properties of the gluten are of greater importance than chemical composition.

4. *Consistency.*—The effect of environment on the consistency of the wheat grain, *i.e.*, its translucent or starchy appearance has been perhaps more thoroughly investigated than any other aspect of the question. There is no doubt that consistency depends very largely on the soil, on the available moisture and on the nutrition of the crop.[4] From the milling point of view the consistency of the wheat grain is of the highest importance and to some extent determines the value of the crop. Differences in consistency affect the market value of wheat in two ways. Firstly, millers like wheats of uniform consistency as in the conditioning or adjustment of water previous to grinding, it is an advantage to handle hard and soft wheats separately and a mixture of hard and soft wheats often leads to trouble and loss. Secondly, as a rule,

[1] Cserháti, *Ztschr. landw. Versuchsw. in Oesterreich*, 9 (1906), No. 10.

Hall, *Journal of the Board of Agriculture (England)*, Vol. XI, No. 6.

[3] Wood, *Journal of Agricultural Science*, Vol. II, 1907, p. 160.

[4] Howard and Howard, l. c.

translucent grains behave better in the mill and are more free grinding. As strong varieties of wheat are generally translucent, translucency is sometimes considered to be an indication of strength, but this is not always the case as translucent weak wheats also occur.[1] In spite of this fact, however, the consistency or appearance of the grain is a very important factor in the commercial valuation of a wheat.

5. *Quality.*—Good quality in wheaten flours has been defined by Humphries[2] as "the sum of excellence on several points," and these points are five in number: (1) flavour; (2) colour of the flour; (3) strength, *i.e.*, size and shape of loaf; (4) stability of dough; (5) yield of bread per sack of flour. It is clear that excellence on such points cannot be determined in any other way than by milling and baking tests. Many attempts have been made to obtain a criterion for the estimation of strength, but so far without success, and in seeking information on the effect of environment on the quality of the grain, it is absolutely necessary to submit the sample to a complete test in the mill and bakehouse.

Although during recent years a certain amount of attention has been paid to the effect of external conditions, such as soil, moisture and manurial treatment on the composition of wheat, but little work has been attempted on the much more important practical question of the influence of environment on the milling and baking qualities. The experiments described in this paper were designed to throw light on this point and also on the change in consistency.

Perhaps the most interesting results on the influence of external conditions on the composition of wheat are those of Le Clerc[3] in the United States, who found in the case of several durum wheats that in humid districts and under excessive irrigation the grain became starchy with a lower proteid content, while in the drier localities the grain remained hard and flinty with a much higher

[1] Biffen, *Journal of Agricultural Science*, Vol. III, 1909.

[2] Humphries, *Quality in wheaten flour*, summary of a paper read before the Joint Session of the Chemistry, Botany and Agricultural Sections of the British Association at Winnipeg, 1909.

[3] Le Clerc, *Yearbook of the United States Department of Agriculture*, 1906, p. 198.

nitrogen percentage. No milling and baking tests, however, seem to have been made by Le Clerc, an omission which greatly reduces the value of his work.

In Canada, Shutt[1] has recently published some observations of a somewhat similar nature. It appears that in certain districts of the North-West when hard wheat is grown on newly cleared scrub land (locally known as "breaking"), there is a tendency to the production on such land of soft or so-called "piebald" wheat. Such grain is much lower in nitrogen content than the original hard wheat used for seed, and is considered in consequence to be a deteriorated product. The same seed (Red Fife) was sown on "breaking" and summer-fallow land, the soil moisture was determined and the resulting crops were analysed. With one exception it was found that both the nitrogen content and the consistency were affected by growth on the newly cleared land compared with the sample obtained on summer-fallow land. On the newly cleared land the grain was soft and starchy with a low nitrogen content, while that grown on the older wheat land was hard and high in proteids. In the following year (1906), the soft sample was sown on freshly cleared land and also on land which had been under wheat for some years. The former gave a soft sample low in proteid like that sown whereas the older wheat land produced a flinty grain high in nitrogen. The results are apparently due to the much greater moisture content of the newly cleared land which prolonged the growth, deferred ripening thus permitting of the deposition of more starch. It is unfortunate that no milling and baking tests seem to have been made with these samples, and that analytical data alone were secured.

Some attention has been paid to these questions by continental observers. Eriksson,[2] in Sweden, found that the consistency of the grain was of no systematic value and depended more on the season than the kind. Koernicke[3] at Popplesdorf, found that there was often a change from floury grain to flinty and also the reverse, and that these changes depended both on soil and season.

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[1] Shutt, *Report of the Fourth Annual Meeting of the Canadian Seed Growers' Association*, Ottawa, 1908, p. 52.

[2] Eriksson, *Die landw. Versuchs-Stationen*, Bd. 45, Heft 1 and 2, 1894.

[3] Koernicke, *Die Arten und Varietäten des Getreides*, Berlin, 1885.

Fruwirth[1] in a recent discussion of the subject concludes that quality varies with the season, soil and the nutrition of the crop, and that in Europe wheats become increasingly floury from East to West and from South to North.

The relation between the quality of wheat and the climatic conditions under which it is grown has been discussed at length by Schindler.[2] This observer considers that climate exercises a paramount influence on the quality of the wheat grown in any tract and that the influence of the race is of secondary importance. His most reliable data are drawn from a study of the Hungarian wheats. By considering the climatic conditions of the five tracts into which Hungary can be divided, Schindler shows that in those districts which have a larger rainfall and more moderate temperature, wheats are produced which are starchy and have larger, heavier grain and a lower protein content than those produced in the drier hotter tracts. An extension of these results was made to include the wheats of other countries. Evidence is also adduced to show that wheats when taken from one locality to another change in weight, size of grain and in protein content in a similar manner. As a result of these investigations Schindler considers that the wheat-growing districts of the world can be divided into "climatic provinces," and he states his conclusions as follows :—"*Im ganzen aber ergiebt sich aus den obigen Zahlen die sehr wichtige Thatsache, dass es nicht gerecht-fertigt ist, von der Korngrösse und dem Proteinanteil der Zucht abs von Rasseneigenschaften zu sprechen.* Sie mögen es ja bis zu einem gewissen beschränkten Grade sein, *allein die Konstanz der Rasse wird in dieser Beziehung durch der Einfluss des Klimas, teilweise auch des Bodens und der Kultur weitaus uberragt.*"

Schindler's conclusions are, however, open to the criticism that in considering the question too many assumptions have been made as to the identity of different races. His Hungarian results for instance are based on the assumption that all the wheat grown in the country is of one type. *A priori* it seems most unlikely that

[1] Fruwirth, *Die Zuchtung d. landw. Kulturpflanzen*, Bd. IV., 1907.

[2] Schindler, *Der Weizen in seinen Beziehungen zum Klima, und das Gesetz der Korrelation*, Munich, 1893.

this should be so. In considering the wheats of other countries no attention is paid to the question of variety at all, and this is a very serious objection to the acceptance of his results as an accurate study of the subject.

More recently Raum[1] at Munich undertook a study of the morphological changes induced in the grains of cereals by climatic conditions. Thirty-five different kinds of wheat mostly of foreign origin were grown for three years and the weight of 1,000 grains and the measurements of the length and breadth of the grain compared with that of the original seed. The results were not very conclusive. In general it was shown that wet summers produced heavier grain than dry years, but it was not possible to determine any progressive change in the length and breadth of the grains by continued cultivation in a new locality. As regards the consistency it was noticed that the North German and exotic kinds became more and more flinty each year and tended to resemble the flinty Bavarian kinds.

In England in addition to the observations of Voelcker[2] (who found at Woburn that as the relative proportions of lime and magnesia in the soil approach nearer and nearer to the ratio 1 : 1 so the wheat grain tends to become more glutinous and hard), a considerable amount of attention has been paid to the effect of external conditions on the milling and baking qualities of wheat by Humphries and Biffen.[3] These investigators grew two wheats differing in strength on seven types of soil and found that while the soil had a considerable influence on the strength yet on all soils the stronger variety, Red Lammas, gave the better result. The bakers' marks of Red Lammas varied from 70 on warp land to 50 on a stony clay soil.

1 Raum, *Zur Kenntniss der morphologischen Veranderungen der Getreidekörner unter dem Einflusse kleimatischer Verhaltnisse*, Munich, 1906.

2 Voelcker, *Journal of Royal Agricultural Society of England*, Vol. 68, 1907, p. 265.

3 Humphries and Biffen, *Journal of Agricultural Science*, Vol. II, 1907, p. 6.

II. THE INDIAN PROBLEM.

The conditions, both as regards soil and climate under which wheat is grown in India, vary very widely. There are several well-marked wheat tracts differing from each other in the nature of the soil, in the sources of moisture and in the growth period. Wheat-growing on the Chenab colony, for example, is very different from that on the black cotton soils of the Narbada valley in the Central Provinces.

The wheat tracts of India fall into two main groups differing both as regards soil and also as regards the source of moisture. The more important of these regions is the alluvium of the Indo-Gangetic plain stretching from Bihar on the East through the United Provinces and the Punjab to Sind on the Western Coast. In parts of Bihar, wheat is grown on low-lying high moisture retaining heavy loams without irrigation. In Oudh, wells supplement the rainfall, while in the Doab between the Jumna and the Ganges and in the western Districts of the United Provinces canal water is largely employed. Well irrigation is again met with in the Eastern Punjab while in other portions of the Province the wheat crop obtains most of its moisture either from perennial or inundation canals. In Sind, inundation from the Indus takes the place of the monsoon. The predominant feature of the wheat tracts of the plains is some form of irrigation and the crop may be either entirely or only partially watered.

The second group of wheat-growing tracts in India is found in Peninsular India principally on the black cotton soils of Central India and Bombay. Here irrigation is largely confined to the second class wheat soils of Bombay, most of the wheat of the Peninsula being raised on the moisture left in the soil after the previous monsoon.

In both of these regions the first consideration is moisture. If the tract is commanded by a perennial canal the choice of soil

is not of paramount importance, any type of loam being used for wheat. Where the natural rainfall is supplemented from wells as in Oudh, wheat is confined to rather heavy loams with a moderate capacity for retaining moisture. In tracts which are not irrigated at all as in North Bihar and the Central Provinces, the type of soil is of the greatest importance and only heavy soils which retain moisture well are used for wheat.

Another factor, in addition to soil and moisture supply, is of great importance in wheat-growing in India, namely, the length of the growth period in the various tracts. The wheats of Peninsular India and Bihar are rapidly maturing forms and in these regions any wheats requiring a longer period for growth than those now in cultivation are bound to be unsuitable. In these tracts wheats are sown towards the end of October and reaped during the second half of February and the first half of March. In the United Provinces and the Eastern Punjab the harvest is later, while in the canal colonies of the Punjab wheat is ripe at the end of April.

Besides these cultural differences, certain of the wheat tracts of India have gained a reputation for producing certain types of grain. Thus the wheat exported from the Narbada valley gives a flour of a very chalky white hue, while the wheat from the Muzaffarnagar District has a very plump soft grain—other tracts such as parts of Bengal appear to produce small flinty grains. It is obvious that in the introduction of new varieties it becomes a matter of great moment to find out whether such new wheats will retain their characteristics in new districts or whether they will acquire to some extent the characters of the wheat generally grown in such tracts. If, as appears probable from the results already obtained, it is found that environment exercises a very marked effect on the quality, it is clear that one of the problems in the improvement of wheat in the Indian Empire will be to ascertain what are the characters of the wheat crop in the various tracts, the extent of these tracts and how far it is possible to usefully distribute new and improved varieties. This will enable a scientific scheme of seed distribution to be drawn up for the whole of India.

Little useful information on the quality of the wheat grown in the various tracts can be gained from an examination of the crop as grown by the cultivators as their fields are so mixed and often contain at least a dozen different botanical varieties often belonging to two subspecies. Further, these mixtures vary from year to year as many of the cultivators do not keep their own seed but obtain the seed wheat from the grain dealers. While an examination of these variable mixtures gives a general idea of the consistency of the crop likely to be raised in any tract, they are not of much use for milling and baking tests as they always contain so many classes of red and white grain often mixed with durum wheat.

The method adopted in this investigation is to compare, as regards consistency, absolute weight, milling and baking qualities, several pure types of wheat grown at various stations according to the manner in vogue among the best cultivators in each place. Care is taken to select really typical wheat soil and to carry out the cultivation according to the ordinary practice of the locality. In this manner the product fairly represents the result which would in practice be obtained by introducing such a wheat among the cultivators. The several stations have been selected so as to include as many as possible of the most important wheat-growing tracts of the Indo-Gangetic plain from the canal colonies of the Punjab to the banks of the Ganges in Bengal and also two stations representative of the black cotton soil tracts of Peninsular India. At each station several wheats are grown of markedly different qualities. These wheats are all pure types, that is, they are both agriculturally and botanically uniform. Full cultural details are kept and thus the same wheat grown at the different stations can be compared both as regards its behaviour in the field and as regards the character of the resulting produce.

The weight of 1,000 grains is obtained, the consistency is determined and the samples are then sent to be milled and baked in England by Mr. A. E. Humphries,[1] the Chairman of the Home-grown Wheat Committee of the Incorporated National Association

[1] For an account of the method adopted in carrying out these milling and baking tests, see Humphries and Biffen, *Journal of Agricultural Science*, Vol. II, 1907, p. 1.

of British and Irish Millers, and a well-known authority on the milling and baking of wheat. It is hoped to grow these wheats for several years at each station, the seed used in each succeeding year being drawn from the wheat produced at the same station in the preceding year.

When a sufficient number of well-chosen types of wheat, representative of the various classes grown, have been tested for several years in this manner it will be possible to determine with precision how far milling and baking qualities are affected by environment and whether such a change is progressive or whether it takes place once for all. The type of wheat best suited to the various tracts will at the same time be discovered, and it may be possible to draw up a scientific scheme of seed distribution for India. Unprofitable work in trying to grow in any tract wheats entirely unsuited to it will in future be prevented.

Strong free-milling wheats can certainly be grown in some tracts of India, others at the present time are producing weak soft whites of poor milling qualities. It is obviously important to discover how far the profitable cultivation of high quality wheats can be extended and whether in the tracts now growing soft grain, strong wheats can be made to retain their strength and high milling qualities.

The results obtained in 1908 and 1909 are of considerable interest and during the present wheat-growing season, 1909-10, the experiments have been considerably extended.

III. THE RESULTS OBTAINED IN 1908 AND 1909.

A. *Muzaffarnagar white.*

During the season 1907-08, Muzaffarnagar white, (*T. vulgare* Vill. var. *graecum* Kcke.) a weak soft white type obtained from Muzaffarnagar was grown at three stations, Lyallpur, Muzaffarnagar and Púsa. At Lyallpur and Muzaffarnagar the wheat was grown under canal irrigation while at Púsa it was raised on the moisture left in the soil from the previous monsoon. Both in appearance, consistency, nitrogen content and milling and baking value the three resulting samples varied widely as will be seen from the following table :—

Consistency, composition and baking value of Muzaffarnagar white grown at three stations in 1907-1908.

Where grown.	Colour and Consistency.	% Nitrogen (Leather).	Order in baking value (Humphries).
1. Púsa ..	Amber, mostly hard and semi-hard.	1·86	Fifth.
2. Lyallpur ..	Dull white, mostly soft and mottled.	1·50	Eighth.
3. Muzaffarnagar ..	White, entirely soft.	1·38	Ninth.

The great differences between the Púsa grown sample and the other two suggested the desirability of repeating the tests on a wider basis and accordingly a fresh supply of Muzaffarnagar white seed was obtained by one of us from Muzaffarnagar and arrangements were made to grow it under normal conditions on typical wheat land at the following stations—Púsa, Bankipore, Dumraon, Partabgarh, Cawnpore, Orai, Aligarh, Meerut and Lyallpur. The sample contained 90% soft grains and 10% hard. It will be seen from the accompanying map that these stations represent most of the important wheat-growing tracts. Púsa is

representative of North Bihar; Bankipore and Dumraon of South Bihar; Partabgarh of Oudh; Cawnpore of the Middle Doab, while the Upper Doab is represented by Aligarh and Meerut. Lyallpur is situated in a canal colony of the Punjab and Orai represents the Bundelkhand. During 1909-10, Hoshangabad has been included, a station typical of the true black cotton soil found in the Narbada valley.

The results obtained at the nine stations in 1908-09 proved to be still more interesting than the preliminary results obtained at Lyallpur, Muzaffarnagar and Púsa in 1907-08.

1. *Cawnpore.*—This sample was grown in the Botanical area at the Cawnpore Experiment Station by the Economic Botanist. Cawnpore is typical of the large wheat-growing tract known as the Middle Doab. The cultural and other details are given in the following table :—

Trial of Muzaffarnagar white at Cawnpore, 1908-09.

Cultural and other details.

1.	Type of soil	Typical wheat loam known locally as *dumat.*
2.	Previous crop	Oats.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop	Ploughed six times before sowing on 12-4-08, 3-7-08, 27-8-08, 11-9-08, 28-9-08 and 6-10-08.
5.	Date and method of sowing ..	Sown on 24-10-08, behind the country plough and levelled with the beam.
6.	Seed rate	120lbs. to the acre.
7.	Rainfall, April to Oct. and during growth period	31·68″ during the seven months previous to sowing, 0·25″ during the growth period.
8.	Irrigation	Watered twice from the canal on 22-11-09 and 15-1-09.
9.	Date of harvesting	3-4-09.
10.	Growth period	161 days.
11.	Consistency of sample	8% soft, 48% intermediate and 39% hard.
12.	Nitrogen content	2·37%
13.	Weight of 1,000 grains	35·69 grammes.
14.	Order of merit in commercial value ..	First.

2. *Púsa.*—This sample was grown in the Botanical area at Púsa in North Bihar on typical wheat loam of high moisture retaining capacity. This soil is low in phosphoric acid but contains about 30% of calcium carbonate.

Trial of Muzaffarnagar white at Púsa, 1908-09.

Cultural and other details.

1.	Type of soil	Heavy loam.
2.	Previous crop	Wheat in 1907-08. Fallow during the *kharif* of 1908.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop	Ploughed 7 times during the hot weather and rains.
5.	Date and method of sowing ..	Sown on 26-10-08 behind the country plough and levelled twice with the beam.
6.	Seed rate	60lbs. to the acre.
7.	Rainfall, April to October and during the growth of the crop.	18·84″ April to October and 0·38″ during the growing period.
8.	Irrigation	Once in December 1908.
9.	Date of harvesting	25-3-09.
10.	Growth period	151 days.
11.	Consistency of sample	16% soft, 59% intermediate and 25% hard.
12.	Nitrogen content	2·0%.
13.	Weight of 1,000 grains	38·35 grammes.
14.	Order of merit in commercial value ..	Second.

3. *Partabgarh.*—This sample was grown by the Assistant-Director of Agriculture at the Partabgarh Experiment Station on typical wheat loam. Similar soil at the station contained 0·2% phosphoric acid, 0·36% potash and 0·042% of nitrogen.

Trial of Muzaffarnagar white at Partabgarh, 1908-09.

Cultural and other details.

1.	Type of soil	Typical wheat loam known locally as *dorasa.*
2.	Previous crop	Sugarcane, reaped in February 1908.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	Ploughed five times with the Watts plough (10-7-08, 25-7-08, 6-8-08, 18-8-08, 25-8-08) and five times with the country plough (4-9-08, 14-9-08, 21-9-08, 29-9-08 and 5-10-08.)
5.	Date and method of sowing ..	Sown on 15-10-09, behind the country plough.
6.	Seed rate	108lbs. per acre.
7.	Rainfall, April to October and during the growth period.	22·20″ during the seven months previous to sowing, 0·42″ during the growth period.
8.	Irrigation	Twice from well on 27-10-08 and 31-12-08.
9.	Date of harvesting	29-3-09.
10.	Growth period	165 days.
11.	Consistency of sample	36% soft, 33% intermediate and 31% hard.
12.	Nitrogen content	1·79%.
13.	Weight of 1,000 grains	40·02 grammes.
14.	Order of merit in commercial value ..	Third.

4. *Dumraon.*—This sample was grown by the Deputy Director of Agriculture, Bengal, at the Dumraon Experiment Station on typical wheat land by the method ordinarily adopted by the cultivators in the neighbourhood.

Trial of Muzaffarnagar white at Dumraon, 1908-09.

Cultural and other details.

1.	Type of soil	A clayey loam.
2.	Previous crop	*Aus* paddy.
3.	Manuring	Cowdung at the rate of 83 mds. per acre on 5-10-08.
4.	Preparation of the land for the wheat crop.	Ploughed three times on 15-9-08, 6-10-08, and 17-10-08, and irrigated on 17-9-08 and 8-10-08, from the canal.
5.	Date and method of sowing ..	Sown on 18-10-08 with the single coultered native drill, after which the land was left rough.
6.	Seed rate	100lbs. per acre.
7.	Rainfall, April to October, and during the growth period.	19·93″ during the seven months previous to sowing, 0·9″ during the growth period.
8.	Irrigation	Watered four times from the canal on 6-11-08, 10-12-08, 9-1-09 and 26-2-09.
9.	Date of harvesting	17-3-09.
10.	Growth period	150 days.
11.	Consistency of sample	72% soft, 21% intermediate, and 7% hard.
12.	Nitrogen content	1·52%.
13.	Weight of 1,000 grains	43·67 grammes.
14.	Order of merit in commercial value ..	Fourth.

5. *Aligarh.*—This sample was grown by the Deputy Director of Agriculture of the United Provinces, Northern Circle, at the recently acquired Experimental Station at Aligarh in the Upper Doab.

Trial of Muzaffarnagar white at Aligarh, 1908-09.

Cultural and other details.

1.	Type of soil	Light loam—fairly typical wheat land.
2.	Previous crop	Cotton.
3.	Manuring	Poudrette containing 50lbs. nitrogen per acre.
4.	Preparation of the land for the wheat crop.	Ploughed twice with the Watts plough on 10-2-08, 11-7-08 and eight times with the country plough on 23-8-08, 7-9-08, 11-9-08, 18-9-08, 3-10-08, 4-10-08, 3-11-0 and 6-11-08.
5.	Date and method of sowing ..	Sown on 8-11-09 behind the country plough.
6.	Seed rate	100lbs. per acre.
7.	Rainfall, April to October, and during the growth period.	34·92″ April to October, 1·48″ during the crop.
8.	Irrigation	Four times—on 8-11-08, 8-12-08, 9-2-09 and 9-3-09.
9.	Date of harvesting	5-4-09.
10.	Growth period	158 days.
11.	Consistency of sample	76% soft, 15% intermediate, and 9 % hard.
12.	Nitrogen content	1·30%.
13.	Weight of 1,000 grains	42·54 grammes.
14.	Order of merit in commercial value ..	Fifth.

6. *Meerut.*—This sample was grown by a local *zamindar* near Meerut in the country fashion. This station was selected as the general agricultural conditions of this tract are identical with those in the neighbouring Muzaffarnagar District, and it may, therefore, be taken as the natural home of Muzaffarnagar white.

Trial of Muzaffarnagar white at Meerut, 1908-09.

Cultural and other details.

1.	Type of soil	Typical wheat loam.
2.	Previous crop	Juar.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	The field was ploughed 9 times with the country plough—3 times during the rains and 6 times afterwards.
5.	Date and method of sowing ..	Sown on 21-10-09, behind the country sowing plough.
6.	Seed rate	60lbs. per acre.
7.	Rainfall, April to October, and during the growth period.	34·70″ April to October, and 2·73″ during the growth period.
8.	Irrigation	Three times—20-11-08, 1-1-09 and 15-2-09.
9.	Date of harvesting	12-4-09.
10.	Growth period	173 days.
11.	Consistency of the sample ..	Through an oversight this was not accurately ascertained, but the sample greatly resembled that grown at Aligarh.
12.	Nitrogen content	1·34%.
13.	Weight of 1,000 grains	Not ascertained.
14.	Order of merit in commercial value ..	Sixth.

7. *Bankipore.*—This sample was grown by the Deputy Director of Agriculture at the recently acquired Experiment Station at Bankipore.

Trial of Muzaffarnagar white at Bankipore, 1908-09.

Cultural and other details.

1.	Type of soil	Heavy clay.
2.	Previous crop	Maize (removed in Oct. '08).
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	Ploughed 6 times with the country plough on 1-11-08.
5.	Date and method of sowing ..	Sown on 11-11-08, with the local one coulter drill.
6.	Seed rate	98lbs. per acre.
7.	Rainfall, April to October, and during the growth period.	17·46″ from April to October, 2·79″ during the growth period.
8.	Irrigation	Irrigated on 1-11-08 before sowing and once on 25-1-09.
9.	Date of harvesting	24-3-09.
10.	Growth period	133 days.
11.	Consistency of the sample	83% soft, 13% intermediate and 4% hard.
12.	Nitrogen content	1·34%.
13.	Weight of 1,000 grains	38·95 grammes.
14.	Order of merit in commercial value ..	Seventh.

8. *Lyallpur.*—This sample was grown at the Lyallpur Experiment Station in the Chenab Colony by the Professor of Agriculture of the Punjab Agricultural College. The conditions at Lyallpur are typical of those obtaining in the Chenab Colony which furnishes a large portion of the wheat exported from Karachi. It is, therefore, very important that Lyallpur should be included in this scheme of experiments.

Trial of Muzaffarnagar white at Lyallpur, 1908-09.

Cultural and other details.

1.	Type of soil	Typical wheat land of the Lyallpur District.
2.	Previous crop	Wheat 1907-08, fallow during the *kharif* of 1908.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	Ploughed six times on 19-7-08, 9-8-08, 27-8-08, 9-9-08 and 22-9-08 and irrigated twice on 14-7-08 and 21-10-08.
5.	Date and method of sowing.	Sown on 9-11-08 behind the country plough, levelled with the *Sohaga.*
6.	Seed rate	64lbs. per acre.
7.	Rainfall, April to sowing time and during the growth period.	18·26″ April till sowing time, 3·51″ during the growth period.
8.	Irrigation	Three times on 26-1-09, 27-2-09 and 3-4-09.
9.	Date of harvesting	1-5-09.
10.	Growth period	173 days.
11.	Consistency of the sample	75% soft, 20% intermediate and 5% hard.
12.	Nitrogen content	1·52%.
13.	Weight of 1,000 grains	37·08 grammes.
14.	Order of merit in commercial value ..	Eighth.

9. *Orai.*—This sample was grown by the Deputy Director of Agriculture, United Provinces, Central Circle, at the Orai Experiment Station in Bundelkhand. The soil was a black moisture retaining clay known as *mar.*

Trial of Muzaffarnagar white at Orai, 1908-09.[1]

Cultural and other details.

1.	Type of soil	Typical wheat land known locally as *mar.*
2.	Previous crop	Gram in the *rabi* of 1907-08.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	Bakhared four times—8-6-08, 23-9-08, 9-10-08 and 20-12-08.
5.	Date and method of sowing ..	Sown on 19-10-08 and re-sown on 21-12-08 behind the country sowing plough.
6.	Seed rate	108lbs. per acre.
7.	Rainfall, April to Oct., and during the growth period.	27·90″ April to October, and 3·80″ during the growth period.
8.	Irrigation	Watered three times on 19-10-08, 22-11-08 and 10-2-09.
9.	Date of harvesting	25-4-09.
10.	Growth period	125 days.
11.	Consistency of the sample	95% soft and 5% intermediate.
12.	Nitrogen content	1·93.
13.	Weight of 1,000 grains	30·97 grammes.
14.	Order of merit in commercial value ..	Ninth

[1] This sample is to some extent abnormal as the plot had to be re-sown late in December.

These nine samples were submitted to Mr. A. E. Humphries for milling and baking tests in May 1909 and his report is given below.

REPORT BY MR. A. E. HUMPHRIES, PAST PRESIDENT OF THE INCORPORATED NATIONAL ASSOCIATION OF BRITISH AND IRISH MILLERS, ON THE NINE SAMPLES OF MUZAFFARNAGAR WHITE SENT FROM INDIA IN 1909.

Muzaffarnagars.

"I received 10 lots of this name. One of them, No. 7, is described as Beardless Muzaffarnagar. I know nothing of this wheat as regards its other botanical characteristics, but from my standpoint, as a miller, it is substantially different to the others, and I propose dealing with that separately later on. I understand that the other 9 lots were sown, each one at a different place to test the effect of environment on quality. The results are striking especially if the seed sown in each case had been taken from the same original bulk. I examined the wheats by eye and put them in the following order as regards appearance :—

No. 11. Cawnpore.
,, 15. Púsa.
,, 12. Partabgarh.
,, 13. Dumraon.
,, 10. Aligarh.
,, 9. Meerut.
,, 14. Bankipore.
,, 8. Lyallpur.
,, 16. Orai.

The Orai was a dingy-looking shrivelled wheat, the Lyallpur had a peculiar hue which may have been caused by its having been cut at a much earlier stage of ripeness than the others. There is, in my opinion, a difference of several shillings per quarter in money value between the best and the worst of these lots. This type of

wheat would commend itself to those millers who want to produce soft white flour. It would find a ready sale, say in Ireland, or some parts of the N. E. of England, or in other parts in the absence of English or Australian wheats, and it may be good for biscuit and pudding making, but to me, as a miller, making bread flour for the London district, it is not a desirable type of Indian wheat. It behaves poorly in milling after conditioning, and this remark applies to all of them, particularly to the Orai and Lyallpur lots. Some of the lots contain a proportion of translucent berries. They help the milling and improve the results in bread, but diminish the mere whiteness of the flour. The baking trials leave them very much in the same order as that I assigned to them by appearance, except that the poor looking Lyallpur lot made better bread than its appearance led me to expect, and the Bankipore yielded the worst bread of all on each trial. Some of them, notably the 3 at the head of the list, and in particular the Cawnpore lot, made loaves of good external appearance ; the rest yielded loaves with a pale sickly crust, and are, in my opinion, wheats which a British miller would not willingly use by themselves for any sort of bread flour. The Cawnpore lot also yielded bread of relatively good, but still poor flavour. For my own guidance, I have for many years recorded my opinion of flours in marks, as a more convenient means of recording or expressing opinion than words, and though the scale adopted is a purely arbitrary one, and expresses nobody's opinions but those of the people immediately concerned in the baking operations so recorded, it may make the comparisons more intelligible if I give them herein, 'Stability' means the facility with which large masses of dough can be handled by the baker, 'strength' the volume and shape of loaf.

		Stability.	*Strength.*
No. 11.	Cawnpore	84	75
,, 15.	Púsa	84	75
,, 12.	Partabgarh	82	75
,, 13.	Dumraon	78	63

			Stability.	*Strength.*
No. 8.	Lyallpur	.. ..	68	68
,, 10.	Aligarh	.. ..	70	60
,, 9.	Meerut	.. ..	70	60
,, 16.	Orai	.. ..	64	60
,, 14.	Bankipore	.. ..	68	52

I am supposing that this record of baking results will be of value in arriving at the influences of soil, climate and water-supply, but it must be remembered that other points besides baking value go to the making up of commercial value, and having regard to all the points mentioned concerning these wheats, I think my original estimate, based on appearance, is the correct summary of their relative commercial merits. I should like to add that the Home Grown Wheat Committee of the National Association of British and Irish Millers tested, in the earliest years of its existence, the influence on quality of varying sets of natural English conditions. We tested two varieties in each locality and found very great differences in both due to environment, but although the effect of environment was not the same in each case on both varieties, the better wheat in every case yielded the better bread. In our view this showed that the effect of breed was predominant. It would be interesting to see whether the same results would be obtained in India if two or more varieties, each able to thrive under the varying local conditions, were tested in a similar way."

It is interesting to notice that Mr. Humphries considers that there is a difference of several shillings per quarter in money value between the best and the worst of these samples, and that he is further of opinion that "the results are striking, especially if the seed sown in each case had been taken from the same original bulk." This was the case—the seed was obtained from a local *zamindar* in Muzaffarnagar and contained 90% soft grain and 10% hard. For the sake of convenience the results with Muzaffarnagar in 1908-09 are summed up in the following table :—

Comparative value of Muzaffarnagar white grown at nine stations in 1908-09.

Where grown.	Consistency.			Weight of 1,000 grains in grammes.	Nitrogen percentage.	Bakers' marks.		Order of merit in commercial value.
	Soft.	Intermediate.	Hard.			Stability.	Strength.	
Cawnpore	8	48	39	35·69	2·37	84	75	First.
Púsa	16	59	25	38·35	2·00	84	75	Second
Partabgarh	36	33	31	40·02	1·79	82	75	Third.
Dumraon	72	21	7	43·67	1·52	78	63	Fourth.
Aligarh	76	15	9	42·54	1·30	70	60	Fifth.
Meerut	—	—	—	—	1·34	70	60	Sixth.
Bankipore	83	13	4	38·95	1·34	68	52	Seventh.
Lyallpur	75	20	5	37·08	1·52	68	68	Eighth.
Orai	95	5	0	30·97	1·93	64	60	Ninth.

B. Punjab wheats grown at Lyallpur and Cawnpore.

In 1908 the types of wheat grown in the Punjab were botanically and agriculturally classified at Lyallpur and twenty-five distinct wheats were distinguished. An account of this work is given in a previous paper.[1] These 25 wheats were grown in the Botanical area at Cawnpore by one of us in 1908-09, and a comparison was made between the consistency of the original seed obtained from Lyallpur with that which resulted from the Cawnpore harvest in 1909. The results are given in the following table :—

[1] Howard and Howard, *Memoirs of the Department of Agriculture in India* (*Botanical Series*), Vol. II, No. 7, 1909.

The change in consistency of the 25 types of Punjab Wheats when grown at Cawnpore in 1908-09.

Type No.	Botanical name.	Consistency at Lyallpur in 1908.			Consistency at Cawnpore in 1909.			Nitrogen percentage.		Weight of 1,000 grains in grammes.	
		Soft.	Inter-mediate.	Hard.	Soft.	Inter-mediate.	Hard.	Lyallpur.	Cawnpore.	Lyallpur.	Cawnpore.
	T. DURUM Desf.										
1	Var. *melanopus* Al.	9	29	62	0	0	100	1·75	2·60	45·80	43·39
2	Var. *africanum* Kcke. ..	0	9	91	2	5	93	2·61	1·97	50·74	54·65
3	Var. *leucurum* Al.	0	4	.96	24	25	51	2·20	1·56	54·91	52·48
	T. COMPACTUM Host.										
4	Var. *erinaceum* Kcke. ..	17	46	37	19	8	43	2·14	1·63	22·38	27·71
5	Var. *linaza* Kcke.	58	42	0	25	35	40	1·78	1·49	29·54	32·60
6	Var. *Wernerianum* Kcke. ..	100	0	0	100	0	0	1·62	1·80	31·56	34·48
7	Var. *Humboldti* Kcke. ..	23	49	28	39	33	28	1·71	1·58	25·23	31·53
	T. VULGARE Vill.										
8	Var. *barbarossa* Al.	21	31	48	0	6	94	1·52	2·16	32·16	30·38
9	Var. *fuliginosum* Al.	4	15	81	23	23	54	2·01	1·60	32·02	37·06
10	Var. *erythroleucon* Kcke. ..	51	49	0	0	1	99	1·40	1·75	33·55	35·61
11	,, ..	75	25	0	61	29	10	1·34	1·65	35·05	29·14
12	,, ..	0	27	73	1	3	96	1·50	2·00	36·40	35·34
13	Var. *ferrugineum* Al. ..	20	36	44	5	7	88	1·57	1·93	35·04	30·37
14	Var. *erythrospermum* Kcke. ..	29	71	0	0	0	100	1·37	1·90	35·70	35·32
15	,, ..	68	32	0	1	8	91	1·43	2·16	36·44	33·12
16	Var. *græcum* Kcke.	88	12	0	34	1	65	1·39	2·08	33·69	31·38
17	Var. *Delfii* Kcke.	25	31	44	7	8	85	1·42	1·71	35·15	38·54
18	,, ..	69	31	0	2	3	95	1·39	2·26	34·53	31·00
19	Var. *leucospermum* Kcke. ..	83	17	0	1	5	94	1·35	2·29	31·58	22·20
20	Var. *alborubrum* Kcke. ..	73	27	0	0	0	100	1·43	2·10	33·59	32·39
21	,, ..	62	23	15	0	0	100	1·45	2·54	32·40	30·48
22	Var. *milturum* Al.	14	43	43	1	1	98	1·38	2·10	35·07	38·55
23	,, ..	100	9	0	98	0	2	1·35	1·95	33·13	33·83
24	Var. *albidum* Al.	66	16	16	4	11	85	1·37	1·87	36·48	38·04
25	,, ..	92	8	0	99	0	1	1·62	1·52	38·26	41·99

With one exception it will be observed that the common wheats have increased in nitrogen content at Cawnpore, and that are also corresponding changes in consistency. In all cases nitrogen content and the weight of 1,000 grains must be considered together. When the absolute weight is low, the nitrogen content naturally increases, apart from the effect of environment.

Five of the common wheats (Types 10, 12, 15, 17 & 21) were sent to Mr. Humphries for milling and baking tests and his report is given below. It will be noticed that while none of these wheats are particularly strong, some of them mill well and all the white ones (Types 10, 12, 17 & 21) are superior to the Karrachi wheats of commerce :—

Punjab Group.

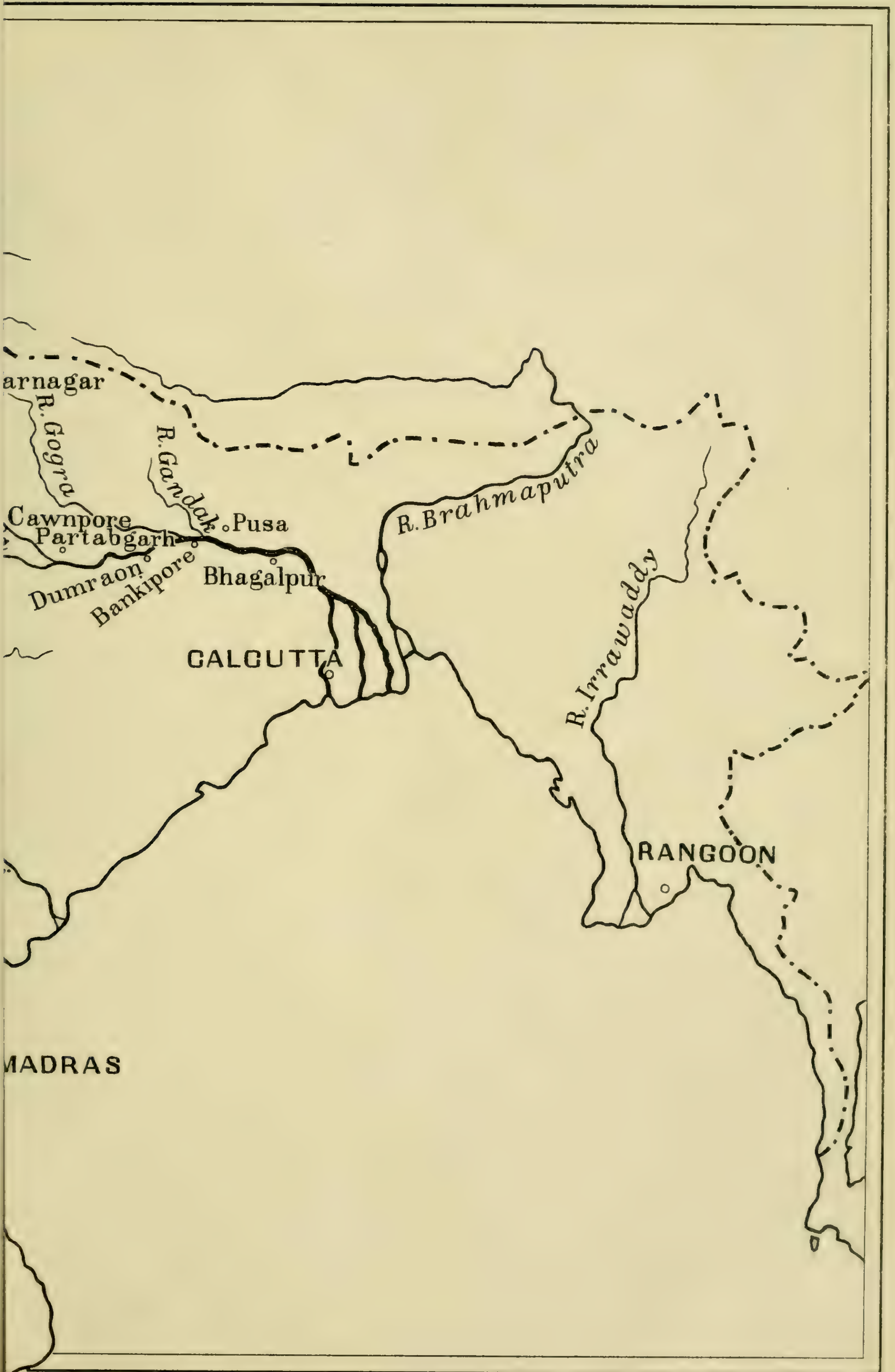
"Nos. 1 to 5 inclusive were also labelled as Punjab 10, Punjab 12, Punjab 15, Punjab 17 and Punjab 21, respectively. In arranging the sequence of groups herein, I have had regard to the hardness of the constituent wheats ; therefore, it may be correctly inferred that these wheats are distinctly harder than those already dealt with. Of this group, No. 3 (Punjab 15), the only red one in it, is the least hard, but even that one milled after conditioning very freely : indeed, on the one point of behaviour in the mill all this group stand highly. Nos. 1, 2, 4 & 5 are of very attractive appearance, and because any one lot of wheat should be even in texture, No. 5 is the best of the group, because it consists entirely of beautifully translucent grain. As a consequence, the flours from this group are not white or soft. Nos. 4 & 5 yield yellow flours, but they are of attractive appearance, and bake well. The bread from No. 5 was of a pleasant flavour. This group provides no surprises as regards strength. The best one on that point is No. 5, but even that behaves like good ordinary Indian wheat. However, all of the white ones are superior to the Kurrachee wheats of commerce. The red one (No. 3) is not 'well grown' and does not 'take the eye' so much as the others of this group."

It will be clear from the milling and baking reports on the nine Muzaffarnagars and on the five Punjab types grown at Cawnpore how exceedingly important it is to consider appearance and

milling quality in the wheats exported to England. It is to the interests both of the cultivator and of all concerned in the wheat trade of India that they should deal with a more valuable product than the present wheats of export. Great care should be taken to place Indian wheat on the market in a clean, dry and uniform condition and as far as possible grain uniform in consistency should be aimed at.

Our experience in Púsa, Cawnpore and Lyallpur shows that the Indian cultivator has much to learn in the growing of wheat and especially in the conservation of soil moisture, in the preliminary preparation of the land, the use of good seed and in the regulation of the irrigation water. In the canal colonies of the Punjab especially great room for improvement exists in these respects. In this important wheat tract the wheat lands should be weathered during the hot season and ploughed occasionally during the summer months. The resulting partial sterilisation of the soil would do much to improve the nitrogen supply of the next crop, any rainfall would be absorbed and a far better seed bed and tilth obtained for the wheat crop. Smaller irrigation compartments should be made, as little water as possible should be used, and the last irrigation should not be delayed too long. In the rest of the Indo-Gangetic plain the substitution of light iron soil inverting ploughs in the place of the country plough for opening out the soil during the hot weather and during the early portion of the monsoon would lead to a vast improvement in wheat-growing. Fewer ploughings with the country plough are desirable towards the end of the preparation so as to conserve soil moisture and produce a better seed bed.

The experiments dealt with in the present paper are only a portion of those in progress on the influence of environment on the quality of Indian wheat. The full scheme of work now in hand is described in the next section.



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IV. THE EXPERIMENTS NOW IN PROGRESS.

The present paper deals only with the earlier experiments and principally with those in which Muzaffarnagar white was used. This wheat was originally selected as it was the only pure wheat available in sufficient quantity for the experiments and also because it represents the soft whites now so much exported to Europe. It is a good example of a weak, soft white wheat yielding a chalky flour. Three other wheats have since been added, namely, three Púsa selections representing (1) a free-milling, high nitrogen, uniformly hard white durum; (2) a soft, mellow, free-grinding, white wheat of great strength and high bread-making quality; and (3) a hard, white, free-milling, strong wheat not unlike Canadian Fife in shape and quality. The influence of environment on these soft strong and hard strong wheats will be of great interest, and it will be seen whether or not a soft strong wheat will retain its strength in localities such as South Bihar, Bundelkhand, the Narbada Valley, the Upper Doab and on the Chenab Colony of the Punjab.

After growing each of the four selected wheats at each station for several years, the various samples will be taken back to their original home, grown side by side and again tested to see if they revert to their original character and become uniform in all respects. The Muzaffarnagars will be grown at Meerut by a local *zamindar*, while the three Púsa selections will be grown in the Botanical area at Púsa.

Besides these trials which will form the main portion of the investigations, other subsidiary experiments will be carried out. The 25 Punjab types of wheat will be grown side by side in the Botanical area at Cawnpore for the next few years and their consistency examined every year. In 1909-10 and following years they will also be grown in the Botanical area at Púsa and similarly examined and compared with the Cawnpore produce. These 25 Punjab types which are absolutely pure both as regards botanical

and agricultural characters form a very convenient material for the study during several years of changes in consistency on a large number of very different wheats. The 25 types include 3 macaroni wheats, 4 dwarf wheats and 18 common wheats. In a similar manner the Bengal types of wheat at present growing in the Botanical area at Púsa will be grown in the Botanical area at Cawnpore from 1910 onwards.

A further experiment on the influence of environment on the milling and baking qualities of wheat is in progress at Cawnpore and Púsa, and it is hoped to extend this experiment to the Chenab Colony of the Punjab in 1910. This trial consists in the influence of weathering[1] on the yield and quality of the same variety grown side by side on quarter acre plots, one of which has been weathered during the hot weather and the other in which cultivation has been postponed till after the monsoon has set in. Both the consistency and the milling and baking qualities of these samples will be compared, and it is expected that the results will not be without interest and value to India.

---

1 The exposure of the alluvial soil of the plains of India by several ploughings to the sun and air during the intensely hot dry weather of April, May and June has an astonishing effect on the yield of the succeeding wheat crop and undoubtedly increases the nitrogen available in the soil as is seen in the dark green luxuriant foliage. When the soil for wheat is not weathered during this hot dry period, the crop is yellow and stunted and exhibits all the characteristics of nitrogen hunger.

The explanation of the extraordinary manurial effect of weathering is no doubt due to the partial sterilisation of the soil by the intense dryness, heat and light of an Indian hot weather. In all probability these causes bring about a similar result to that produced by artificial heating and by poisons such as has been found in England by Russell and his pupils (vide *Journal of Agricultural Science*, Vol. III, 1909, p. 111). These investigators have found that partial sterilisation of the soil kills off the phagocytes which live on bacteria, and also large soil organisms inimical in other ways to bacteria. At the same time the soil bacteria are killed off, but the spores remain which germinate and rapidly multiply when the soil is moistened. The new bacterial cultures increase at an enormous rate and the resulting nitrogenous plant food becomes so great that growth is stimulated. Russell's researches seem to afford an adequate explanation of the extraordinary manurial effect of weathering Indian wheat land. The Imperial Agricultural Bacteriologist has agreed to investigate the bacteriological aspect of this question in India. For weathering during the hot season iron ploughs are more effective than the native wooden plough. This is no doubt due to the better soil inversion produced by the former, resulting in a more complete weathering and sterilisation of the soil.

We believe it will be found that not only the yield but also the quality of the crop is improved by weathering. Where the preliminary weathering is neglected and the wheat lands are not broken up till late, the crop is almost invariably uneven in texture. The preliminary weathering seems to lead to a uniform absorption of monsoon or irrigation water and to prevent local excess or defect of soil moisture. A uniform condition as regards soil moisture is naturally bound up with an even supply of moisture to the crop and this seems to be one of the causes of grain of even texture.

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THE BUD-ROT OF PALMS IN INDIA

BY

E. J. BUTLER, M.B., F.L.S.,

Imperial Mycologist

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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PREFACE.

The following account of the bud-rot of palms in South India is written because the continuance of the work to which it relates has passed from my hands to those of the recently appointed Mycologist to the Madras Department of Agriculture, Mr. W. McRae.

I have pleasure in acknowledging much assistance from the notes of field observations and experiments supplied by Messrs. S. Sundararaman and D. Balakrishna Murti of the Madras Department of Agriculture and S. N. Mitra and R. Sen of the Mycological Laboratory, Pusa.

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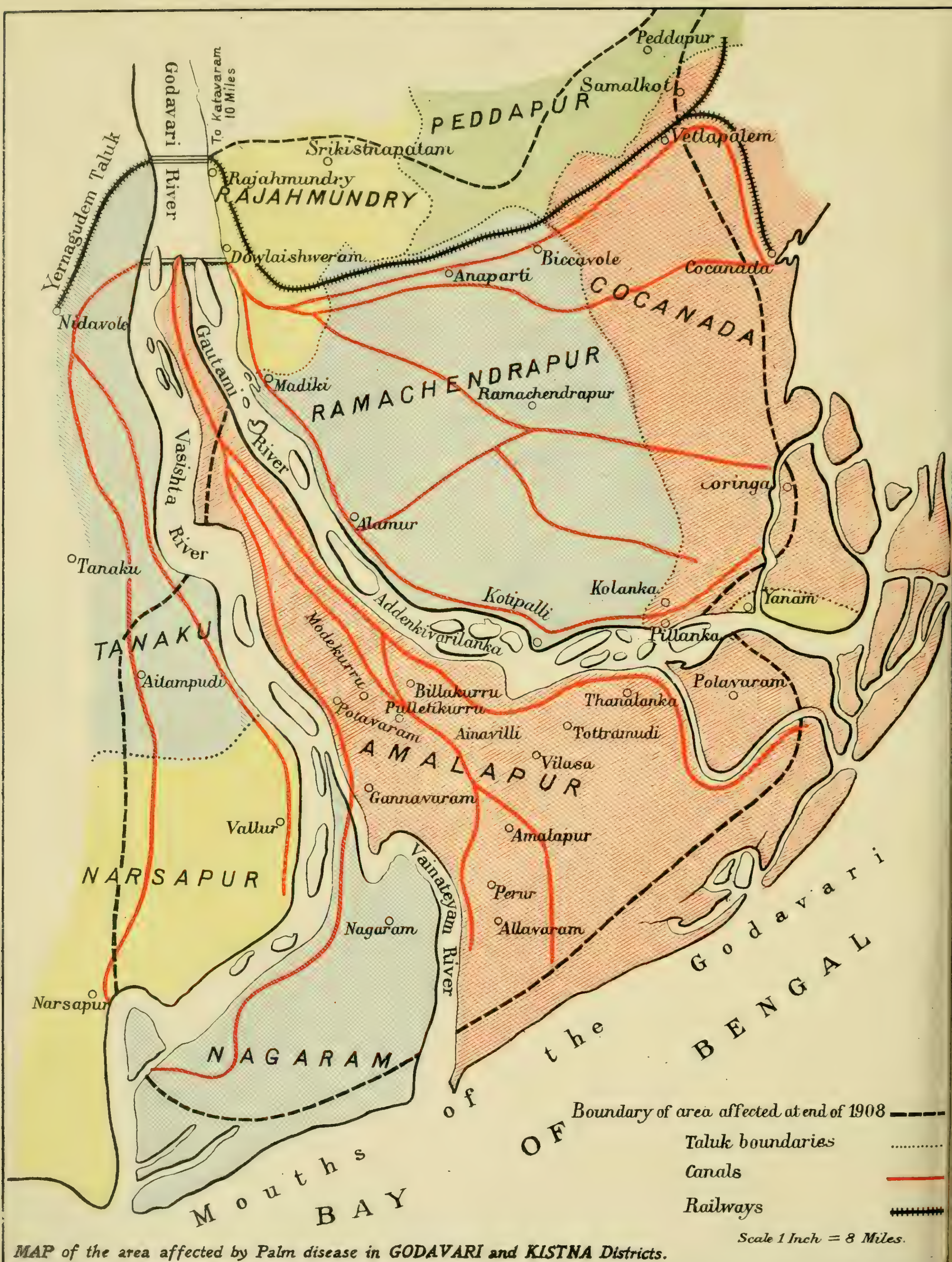

MAP of the area affected by Palm disease in GODAVARI and KISTNA Districts.

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THE BUD-ROT OF PALMS IN INDIA.

BY

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Imperial Mycologist.

I.—INTRODUCTION.

A group of palm diseases, the chief symptom of which is a rot in the soft tissues of the interior of the crown, has attracted much attention in tropical countries in recent years. The "Kew Bulletin" for 1893[1] quotes a description of a coconut disease observed in Jamaica in 1891[2], and states that it appears to be allied to an obscure disease known as coconut "fever" in Honduras and to a disease observed in British Guiana in 1875-6. A similar disease destroyed many coconut groves in Cuba in 1886, and a report on it was published at Havana in 1888. After the occupation of that island by the United States, coconut palms were found to be dying in large numbers from a mysterious disease. In 1901, Mr. A. Busck of the Division of Entomology of the United States Department of Agriculture reported that it was probably caused by the fungus Pestalozzia palmarum, a common palm-leaf parasite, but that bacteria seemed to play some part.[3] Professor F. S. Earle saw the disease in Jamaica in 1902 and believed it to be of bacterial origin.[4] The same view was taken in 1905 by Dr. Erwin F. Smith of the United States Department as regards the Cuba disease.[5] It was next observed in Trinidad by Mr. Hart in 1905, and attention again

[1] W. F. H. Blanford. Palm weevil in British Honduras, Kew Bulletin, 1893, p. 42.

[2] W. Fawcett. Report on the Coconut disease at Montego Bay. Bulletin of the Botanical Department, Jamaica, No. 23, 1891, p. 2.

[3] A. Busck. Report of an investigation of diseased Coconut palms in Cuba. U. S. Dept. of Agriculture, Division of Entomology, Bull. No. 38, N. S., 1902.

[4] F. S. Earle. Report on a trip to Jamaica. Journal of New York Botanical Garden. Jan. 1903.

[5] Erwin F. Smith. Bud-rot of the Coconut palm in the West Indies. Science, N.S., Vol. XXI, 1905, p. 500.

directed to the bacteria present in the rotting tissues.[1] In the West Indian Bulletin for 1906 (Vol. VI, p. 307) there is a general review of the disease in the West Indies, and subsequent accounts of it have been written by Mr. W. T. Horne, Chief of the Department of Vegetable Pathology, Central Agricultural Station, Cuba,[2] by Mr. F. A. Stockdale, Mycologist of the Imperial Department of Agriculture, West Indies,[3] and by Mr. J. R. Johnston of the United States Department of Agriculture.[4] None of these have advanced our knowledge of the cause of the disease, and Mr. Horne records that many inoculations with organisms isolated from the diseased tissues have failed.

In the East bud-rot of coconuts is also widely distributed. It was described by Mr. T. Petch, Government Mycologist, Ceylon, in 1906, affecting a small area.[5] He considered it to be the same as the West Indian disease and attributed it to bacteria. He refers to correspondence with Portuguese East Africa in 1903 which indicates that the same disease occurs there. In the Philippine Islands bud-rot causes great damages in several localities, and an account of it was published in 1908 in the Philippine Agricultural Review.[6]

In 1906 the writer described a severe epidemic of disease in palmyra and other palms in the Godavari District of the East Coast of India.[7] In intensity this surpassed the outbreaks in most other countries, but it was confined to a comparatively limited area in

[1] J. H. Hart. Bud-rot disease of Coconuts, etc. Trinidad Botanical Department, Bulletin of Miscellaneous Information, Oct. 1905, p. 240.

[2] W. T. Horne. The Bud-rot and some other Coconut troubles in Cuba. Estacion Central Agronomica de Cuba. Bulletin No. 15, English Edition, July 1908.

[3] F. A. Stockdale. Fungus diseases of Coconuts in the West Indies. West Indian Bulletin, Vol. IX, 1909, p. 361.

[4] J. R. Johnston. The Bud-rot of the Coconut palm. U. S. Dept. of Agriculture, Bureau of Plant Industry, Circular No. 36, July 1909.

[5] T. Petch. Bud-rot of the Coconut palm. Circulars & Agric. Journal of the Royal Botanic Gardens, Ceylon, Vol. III, No. 15, April 1906.

[6] Philippine Agricultural Review, Vol. I, No. 5, May 1908, quoted in The Tropical Agriculturist, Ceylon, Vol. XXXI, 1908, p. 555.

[7] E. J. Butler. Some diseases of Palms. Agricultural Journal of India, Vol. I, p. 299, Oct. 1906. See also Memoirs of the Department of Agriculture in India, Vol. I, No. 5, 1907, p. 82, and Agricultural Research Institute, Pusa, Bull. No. 9, March, 1908, p. 21.

the Delta of the Godavari River. The cause of the disease was stated, as a result of a field and microscopic examination, to be a fungus belonging to the genus Pythium, a description of which, under the name Pythium palmivorum, was published in these Memoirs in February, 1907. Subsequent investigation (the details of which are given below) has confirmed this statement, and the disease has been several times directly produced in healthy trees by inoculating them with the fungus. A couple of cases of the same disease were found in Travancore on the West Coast of India in 1907, and there is little doubt that it was this fungus which was concerned in a coconut disease in the same State, mentioned in the Indian Forester in 1894 by Mr. A. M. Sawyer.[1] Up to the present the particular parasite which is the cause of bud-rot in India has not been met with in any other country. It is, however, premature to say definitely that the outbreaks mentioned above are all due to a cause different from that in India; there are as yet no published successful inoculations with any other organism, and the fact that Pythium palmivorum is not recorded in the diseased crowns does not altogether preclude its presence, since it cannot be easily detected except in the earlier stages of the disease. On the whole, it appears likely that the disease in the New World is due to a different parasite, while some at least of the outbreaks in the East may prove identical with that in India.

II.—Description of the area affected.

The Godavari River, rising in the Western Ghâts to the north-east of Bombay, crosses the Nizam's Dominions from west to east and bending southward falls into the Bay of Bengal about half way between Calcutta and Cape Comorin. At Dowlaishweram, 40 miles as the crow flies from the sea, it divides into two main branches, an eastern, called the Gautami Godavari, and a western, the Vasishta Godavari. About two-thirds of the way from Dowlaishweram to the sea, the Vasishta Godavari gives off from its left bank a third

[1] Quoted in Ferguson's "All about Coconut planting," Ceylon, 3rd Ed., 1904, p. cxxiv.

main outlet, known as the Vainateyam Godavari. The Delta proper, which begins at Dowlaishweram, thus consists of two large islands—Amalapur Island, bounded on the north-east by the Gautami branch and on the south-west by part of the Vasishta and the Vainateyam branch; and Nagaram Island, bounded on the north-east by the Vainateyam and on the west by the lower portion of the Vasishta branch. The term Delta is, however, extended for administrative purposes to include the tracts lying north-east and west of the river between Dowlaishweram and the sea, so far as is commanded by the irrigation system arising at Dowlaishweram.

The Delta, thus extended, comprises a portion of the administrative District of Godavari, *viz.*, the islands, and the mainland north-east of them, and a portion of the Kistna District, *viz.*, the mainland lying west of the islands. The administrative sub-divisions or "Taluks" included in this area are the following :—

GODAVARI DISTRICT.	"*Eastern Delta*," *i.e.*, the mainland north-east of the river. Most of Ramachendrapur and Cocanada Taluks.
	"*Central Delta*," *i.e.*, the islands. Amalapur and Nagaram Taluks.
KISTNA DISTRICT.	"*Western Delta*," *i.e.*, the mainland west of the river. Tanaku, Narsapur and Bhimavaram Taluks.

Three of the Upland Taluks, lying above the Delta, require also to be mentioned as they are referred to below. These are Rajahmundry and Peddapur, both of which belong to the Godavari District and consist of long stretches of stony waste alternating with wet land, and Yernagudem, belonging to Kistna, an undulating plain, broken by low ranges.

Communications within this area are good. Roads are numerous and the network of the canals in the Delta is largely availed of for boat traffic. The main channels of the river are of considerable size, often exceeding a mile in width, and communications across them are carried out by means of ferries, the only direct access from the right to the left bank being by the great railway and foot bridge, a mile and-three-quarters long, at Rajahmundry, six miles

above the head of the Delta, and the canal aqueduct and footway between Amalapur and Nagaram islands. In the monsoon the river rises considerably, submerging the smaller islands. The mainland and large islands are protected by massive bunds, but much of the low-lying paddy land is flooded by the local rainfall.

The Delta area is the most densely populated[1] and one of the richest of the Madras Presidency, north of the city of Madras. The bulk of the people, of course, live by agriculture, paddy being the chief crop, with various millets, pulses, sesamum, sann hemp, tobacco and sugar-cane as important subsidiary crops. The soil is mostly a heavy dark alluvium and is very fertile, but this fertility has only become available for supporting a large population since the completion of the irrigation system, one of the most remarkable in India, conceived and largely carried out by Sir Arthur Cotton between 1847 and 1852, as the rainfall is badly distributed. The mean temperature at Cocanada averages 82°F. with a mean range of 15°. The annual rainfall averages 40 inches for the Godavari District, but the first four months of the year are practically rainless and the south-west monsoon, which sets in in the middle of June and lasts until September, gives nearly two-thirds of the whole fall.

The natural forest vegetation of the Delta is scanty, no doubt as a result of close cultivation. The commonest species in much of the area is the palmyra palm, which is self-sown or planted along the divisions of the fields, in the villages and in waste spaces. Three other palms occur, the coconut and arecanut, which are grown as garden crops and the former of which is rapidly extending, and the

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[1] The area and population of some of the Taluks are given as follows in the Imperial Gazetteer of India, Vol. XII, 1908:—

Taluk.	Area in sq. miles.	Population in 1901.
Ramachendrapur	296	220,356
Cocanada	294	213,758
Amalapur	506	277,445
Nagaram	137	103,619
Tanaku	371	238,758

date, which grows wild but is scattered. In the upland Taluks the palmyra is even commoner than in the Delta, in places reaching forest density ; the coconut and arecanut are rare.

No other tree in these districts approaches the palmyra in economic value. A complete account of its uses would occupy many pages. An ancient Sanskrit poem professes to enumerate eight hundred and one! Every part of the tree is turned to account. The wood is universally employed in building construction in the villages. The base of the trunk, hollowed out, is used as a canoe in the numerous creeks in the Delta: it also forms an excellent water carrier for short lifts. Several different kinds of fibre are obtained from the leaves, stalks, fruit and interior of the stem. For one of these, extracted by beating from the leaf stalk, a large demand has sprung up recently, and it is extensively exported from the East Coast. The roots are used in medicine; the leaves for baskets, mats, fans, small buckets and a host of other every-day appliances, as well as for writing on. As a food plant it is of considerable importance, the parts eaten being the fruits both young and ripe, but chiefly the young shoot obtained by germinating the nuts. These are heaped together in seed-beds, covered with soil and left for three or four months, when the shoot is found to be from six inches to a foot in length. For a short period of the year these shoots form the staple food of some of the lower classes. From the inflorescence toddy is obtained, which is drunk both fresh and fermented, or made into vinegar, or distilled to make arrack.[1] It is also extensively used in the manufacture of jaggery or raw sugar, over 400,000 palmyra palms being tapped for jaggery in the Godavari District according to the Imperial Gazetteer. This is chiefly in the upland Taluks. Probably the greatest value of the tree after the production of toddy and the supply of food from the young shoots is in the provision of an ample and inexpensive material for thatching. Its leaves are almost the only thatch available throughout the Delta. A

[1] The Abkari revenue from toddy (including tree tax and rentals) averaged over 3 lakhs of rupees per annum between 1900 and 1903. This does not include revenue from country spirits (Godavari District Gazetteer, Vol. II, 1906, p. 42).

large tree will give from 25 to 30 leaves per annum, and as each house requires two or three thousand leaves and is thatched every three or four years, a village of 1,000 houses uses the produce of about 25,000 trees annually.

The palm is so common, grows so freely and requires so little attention, that the outbreak of a disease which destroyed large numbers did not cause much alarm amongst the people. Were it not that the more prized and tended coconuts were also attacked, it is doubtful if information of its existence would even yet have reached the Agricultural Department. That this attitude was mistaken there can be little question : the value of the tree is discounted by its abundance, but it is not too much to say that its disappearance would change the whole economic condition of the Delta. It is significant that in some of the severely attacked districts the price of the cut leaves has risen in the past few years from Rs. 3 to Rs. 9 or 10 per 1,000.

III.—First appearance and spread of the disease.

The disease is said to have first appeared in Addenkivarilanka, an island in the Gautami Godavari belonging to the Ramachendrapur Taluk, about 1890. From this it spread to both banks of the river and extended both along the banks and inland. Amalapur and Ramachendrapur, chief towns of the Taluks of the same names and situated respectively eight and eleven miles inland from the right and left bank of the Gautami near Addenkivarilanka, were reached about 1897. Pillanka (Cocanada Taluk), a village on the left bank, about twelve miles down the river, and Alamur, about eight miles up the river from the same place, are said to have been affected in 1898 or 1899. About 1902 the disease appeared at Vetlapalam, three miles south of Samalkota at the northern extremity of the Eastern Delta and extended into the upland Taluk of Peddapur. By this date in the Eastern Delta much of Ramachendrapur Taluk was affected and extension was going on into Cocanada Taluk and towards the upland districts near Peddapur. At the same time it is probable that all

the northern half of the Central Delta was affected, except towards the head of the Delta and near the sea. Three main lines of extension appear to have been followed in Amalapur Taluk:—One through Billakurru, Modekurru, Pulletikurru and tailing off towards Potavaram, Gannavaram, and the other villages along the Vasishta and Vainateyam branches of the Godavari; another through Ainavilli, Tottramudi and Thanalanka to the littoral villages south of the Gautami, such as Polavaram; and the third from Ainavilli through Vilasa and Amalapur to Perur and Allavaram. Nagaram island is known to have been affected in 1907, but the disease was slight and probably not of long standing.

In the Western Delta, in the Kistna District, the ryots themselves assign to the winter of 1903 the first appearance of the disease. This was in the Taluks of Tanuku and Narsapur which border the Vasishta river opposite to Amalapur and Nagaram. The date was fixed in their minds by the violent cyclones of October in that year which caused damage to many trees. However, a good observer[1] asserts that the disease must have been in some villages before 1900, judging from field appearances. The evidence here seems to suggest that it entered from Amalapur Taluk above Nagaram island, crossing the Vasishta in the direction of the first line of spread in this Taluk referred to above. By 1907 some 50 villages on this side of the river were affected, the majority very recently, and up to the beginning of 1909 fresh villages were continually being reached. The intensity of the disease on this bank of the Godavari is as yet less than elsewhere, and excepting for an area near the boundary between Tanaku and Narsapur Taluks and extending from the river to Aitampudi and Vallur few villages have reported more than scattered cases. The exact area affected in the Kistna District is not yet fully known, but an outbreak has occurred as far to the south as Masulipatam.

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1 Agricultural Inspector D. Balakrishna Murti, to whom I am indebted for valuable information, sketch maps and notes.

In the upland Taluks, besides the extension into Peddapur, scattered cases have occurred along the fringe of the Eastern Delta, particularly near Rajahmundry town and Anaparti and Biccavole villages. A small outbreak was reported at the end of 1908 near Chidipi and Kumaradevam in the upland Taluk, Yernagudem, of Kistna District, and at the end of 1909 cases were found in Katavaram (Rajahmundry Taluk) on the opposite bank of the river, ten or twelve miles distant from the nearest affected village in Rajahmundry. This is the only case so far reported of an apparently isolated centre of disease if we except the southward extension to Masulipatam, about which details are still wanting, and it is highly probable that it is due to infection from across the river.

Except these two localities and Masulipatam the whole of the rest of the area affected by the disease is continuous and is roughly circular in outline. It is quite clear both from the observations made in the field during the past four years and from information gathered from the cultivators, that the spread has occurred in a centrifugal manner from the locality in the Gautami Godavari first infected. Naturally the flow has been more rapid along some lines than others, and barriers such as the main channels of the river and tracts bare of palms have checked extension in some directions for a greater or less period ; on the whole, however, the onset has been remarkably even and regular all round. Thus the eastern limit at Peddapur is some 30 miles from Addenkivarilanka, the southern in Nagaram Taluk about 24 miles, the western in Narsapur over 20 miles and the northern at Rajahmundry about 25 miles.

The rate of spread is, on an average, little over a mile a year, judging from the extension that has occurred in the area as a whole. In places, however, this is certainly exceeded. Thus an extension of between two and three miles occurred along the canal towards the sea near Kolanka, in the nineteen months from August 1905 to March 1907. Anaparti was the limit of the disease to the north in 1905, whereas three years later it had reached to Shrikistnapatam,

a distance of eight miles. From the same place or from Madiki infection spread to Rajahmundry, 13 or 10 miles respectively, in about two years. On the other hand, Vileasavilli is said to have been first attacked in 1906, while Amalapur town, 4 miles distant, was certainly infected before 1900. So also an observer noted that the village of Rajathapalapatnam was still free from disease in 1907, while Vetlapalam, an adjoining village,[1] had it since 1902. This sharp limitation of the disease at the border of the infected area has been several times noted. Near Kolanka, which was almost certainly attacked before 1900, the disease in one direction observed in 1907 diminished from severe (over 50 per cent. of deaths) to little (under 5 per cent.) in two miles, and two miles further on none could be found. Such cases as the last connect with those in which the onflow of infection appears to have received a check which shows some promise of being permanent. These are chiefly to be found towards the sea and are associated with sandy soils, but there is also some evidence that the drier upland tracts above the Delta oppose a barrier which may perhaps be found efficient. There is no doubt that there are at least two entirely distinct sets of factors controlling the extension. The first is meteorological and, other things being equal, the rate of spread will largely depend on the amount of rain, fog, dew and similar conditions. This will be more fully considered below. The second is biological and includes the little understood conditions which determine the virulence of the parasite, and still more, the susceptibility to attack of the victim. These seem to be in the present case closely connected with the influence of the nature of the soil on the palm itself.

Though, in a broad sense, the disease occupies a continuous area, it must not be supposed that it is uniformly distributed within this area. On the contrary, there is the greatest difference in the severity of the attack from village to village and even from field to field. Close observation confirms the view that the nature of the

1 It should be noted here that the term "village" is used in the sense employed by the revenue authorities, and denotes a certain area of land belonging either to one large village or to several hamlets. The first affected portion of the one village might therefore be perhaps a couple of miles from the nearest part of the adjoining unaffected village.

soil exercises an influence on the susceptibility of the palm to attack. Trees along water-courses and in periodically flooded localities, such as paddy fields, die more quickly and in larger proportion than in dry localities. Instances are numerous in low-lying land along the Gautami river and throughout much of the length of the Kousica water-course which traverses the Amalapur Island. In the villages of Ambajipeta, Gangalakurru, Pulletikurru, Modekurru and Isakapudi the deaths have been most numerous along this water-channel. On the other hand, little disease has been found in the light sandy soils of the sea coast villages. In the village of Nimekaya-Kottepalli, three or four miles from the sea and with sandy soil, no disease could be found in 1907, whereas Katrenicona, adjoining inland and with heavier soil, had lost a large number of palms. The black soils appear most to favour the disease. Naturally when the parasite reaches a spot where the palms are in a condition favourable to its attacks, it spreads rapidly and becomes greatly multiplied. As a result, neighbouring trees, even if not highly susceptible, are exposed to more intense and frequently repeated chances of infection than those at a greater distance. Hence, as a rule, around such localities the disease becomes progressively less severe as the distance from the severely diseased locality increases. Such minor centres of disease, around which the number of cases tails off, are common all over the district. A curious case was observed at Coringa at the Eastern limits of the disease in 1907. In a single "tope" or cluster of palms opposite the travellers' bungalow a number of deaths had occurred apparently a considerable time previously, while there was none in any other part of the village seen. The explanation of this was not found; for some reason, not immediately evident, the infectious matter which these trees harboured had not become disseminated to those near by.

Indeed, the actual mode of spread from tree to tree under natural conditions is not yet fully understood. It has been proved that direct application of the parasitic fungus which causes the disease to the crown of a healthy tree leads to infection of the latter.

Contact with a diseased leaf is sufficient to infect a healthy one. The disease spreads from leaf to leaf on the same tree chiefly by contact. It is, therefore, "contagious." How it spreads from one tree to another without contact, as it certainly does, is not so clear.

The following are the chief possible methods of spread from tree to tree: through the air; by human agency; by birds and insects conveying infectious matter on their bodies.

Most epidemic diseases which resemble the bud-rot of palms are spread through the air. The parasites depend for their propagation chiefly on spores, which are set free and are carried into the air by the wind. Alighting on healthy plants they germinate and produce infection. Such are the potato blight, cereal rusts and the like. Pythium palmivorum, which is very similar to the cause of potato blight, produces spores which would be just as capable of causing rapid spread of the disease as those of the latter, provided that they are formed in a position where the wind can easily reach them. This is not often the case, however, since spores have not been found on the surface of diseased crowns, except in the comparatively small number of cases in which the blade, or expanded portion of the leaf, is attacked. In the large majority of cases the seat of attack is the compact mass of leaf bases, the leaf-sheaths, which form a tubular covering to the top of the stem. Having entered the outermost of these, the fungus grows in towards the softer underlying ones and usually does not begin to produce spores until several have been penetrated. Spores have never been found on the hard outer sheaths, but usually occur between the softer inner ones at some distance from the surface. Here they are not exposed to the air and cannot serve as an effective means of propagation. In some cases, however, the young leaf-shoot at the apex of the crown is found to have been attacked in the portion which afterwards becomes the expanded "blade" of the leaf. This usually occurs while it is still small and hidden in the tube of leaf-sheaths, being the result of direct contagion from the latter. In a very few of these cases the parasite has been found still alive when the young leaf has pushed out into the air, and it is probable that in periods

of high humidity or during heavy dews spores would develope in this situation, freely exposed to the wind. A second condition in which there may be air-borne infection occurs when the tube of leaf-sheaths begins to disintegrate as an effect of the disease. In old cases the outer leaf-sheaths wither and fall away and eventually nothing is left but a bare pole. In these old withered sheaths no spores capable of germination have been found, but it is quite possible that they occur, and if this is so, they would be a means of dissemination. A third condition is the result of the stripping of the outer leaves for thatching and still more in some localities for fibre. In the operation the old leaf bases are torn away, and it is not uncommon to see leaf-sheaths that are still almost white from their internal position, exposed. In infected trees this must offer considerable opportunities for aerial dissemination of the spores. It is doubtful how far the above conditions are sufficiently frequent to account for the intensity of the epidemic. It appears that if this were a common method of spread, the area affected would by now be far greater than it is. Air-borne infection is always rapid and instead of the disease being confined to one small district, it would be found throughout the country. However, it is quite possible that the conditions mentioned above are sufficient to permit of a limited aerial dissemination while not enough to cause rapid extension of the infected area.

Dissemination of disease by human agency is particularly likely where, as in bud-rot, the diseased parts of the plant are habitually handled by persons who afterwards come into contact with susceptible portions of healthy trees. As already mentioned, each village uses the produce in leaves of a large number of palmyras for thatching. In addition a large number of trees are tapped for toddy and jaggery. Over 400,000 palms are tapped for jaggery in the Godavari District (mostly in the upland Taluks) according to the Imperial Gazetteer. For both these purposes the bulk of the palms in the district are climbed at intervals. It is the practice of the climbers to strip off the outer sheaths, both because they impede their operations and because they serve for fuel. Hence the inner

fresh, moist and softer sheaths are often exposed. In diseased trees this is just the position in which felted masses of the mycelium of the parasite are found. Fragments of the outer sheaths containing living mycelium no doubt often break off and remain on the person of the climber. The mycelium itself would readily adhere to his knife. It is easy to see that in repeating the operation in a healthy tree there is every chance of his successfully, if unconsciously, inoculating it with the parasite. There are indications in some places that the disease has followed lines of communication used by the people, particularly the ferries across the canals which intersect the district. These are no doubt used by the tappers and the matter would be explained if the infection is conveyed by them. In this district the coconut trees are not tapped for toddy and their leaves are rarely cut. Hence they are seldom climbed. Arecanuts are neither tapped nor are their leaves cut and when climbed it is only to remove the bunches of nuts, which project well away from the stem. It is possible that this explains in part the comparative immunity of these two species of palm.

The part played by insects in disseminating disease is now well known. Most of the cases recorded are in man or animals, malaria, tick fever, sleeping sickness and *surra* being instances. Flies are known to be important disease-carriers. A bacterial disease of potatoes is spread, according to Dr. E. F. Smith of the United States Department of Agriculture, a distinguished authority, by insects which convey the bacillus from plant to plant. In the present disease the parasite, being much bulkier than those concerned in the above cases, could only be carried by large insects. It so happens that palms are infested by several quite big enough to serve the purpose. The best known are the rhinoceros beetle and the palm weevil, the former of which is very common in the district. I have also seen as many as ten scorpions in the crown of a diseased Palmyra. Numbers of birds also frequent the tops of palms. The felted webs of mycelium which are sometimes found on the older sheaths may quite conceivably adhere to the feet of these and be carried from tree to tree. The beetles penetrate into

the heart of the crown and in diseased trees probably emerge from the pupal state within the disintegrating mass. Here they would be likely to come into contact with not only mycelium but spores which would adhere to their bodies. One or two observations bear on this point. The disease is noticeably severe around the huts of the "Madigas," a low class of Pariahs who eat the carcases of animals, and also near the huts of fishermen and other low castes. This may be due to the presence in such localities of the offal of animals, fish, etc., which would attract birds and insects. In the village of Ramachendrapur this fact was particularly visible. The rate of spread is, however, too slow to make it probable that birds play any considerable part, and, on the whole, though insects are probably responsible for some of the spread, their share is likely to be much less than that of the palm climbers.

While, therefore, the way in which infection is spread in individual cases has not been conclusively found, the methods considered above, particularly those connected with the stripping of the leaves by human agency, are probably sufficient to account for the conditions observed.

IV.— Species affected and course of the disease.

As already mentioned, four species of palm are common in the Delta, the palmyra (Borassus flabellifer), the coconut (Cocos nucifera), the areca (Areca Catechu) and the date (Phœnix sylvestris). Of these the first three are subject to the disease, while the date, so far as has been observed up to the present, is immune.

By far the greatest mortality has occurred amongst palmyras. Probably over half a million have been attacked within the affected area. Coconuts have suffered much less. In an enumeration of the diseased palms in the Mummidivaram Firka of Amalapur in 1907, less than 1 per cent. were found to be coconuts (46,527 palmyras, 455 coconuts). This disparity in numbers is not entirely due to the much greater quantity of palmyras than of coconuts actually growing in the area in question. In several places there are large gardens of coconuts surrounded by severely diseased

palmyras and yet containing few cases of the disease. In Muchumilli, a village of Ramachendrapur Taluk, the disease had been prevalent for about six years in palmyras before any coconuts were attacked. Clumps of palmyras in which over 50 per cent. of the trees have been killed are not uncommon, but nothing like this mortality has been found in coconut gardens. Owing to the way in which coconuts are cultivated in large gardens close together and without admixture of other kinds of trees, very favourable opportunities would appear to be afforded for the rapid spread of the disease from the first trees attacked to those surrounding. That this has not occurred may be due in part to the fact mentioned above that there is less opening for accidental inoculation by the palm climbers in coconuts than in palmyras, but probably depends in larger measure on a natural resistance presented by this species to the parasite. Only one experiment has been made which goes to prove that infection of coconuts is less easy than of palmyras. A coconut palm and two palmyras were inoculated on the same day. Examined after a month the former showed a small patch of infection about half an inch in diameter and penetrating less than half an inch of the thickness of the inoculated leaf-sheath, the inner surface of which had not been reached. There had been no obvious increase in the patch since the 8th day after inoculation. In the palmyras the progress was much more rapid, the inoculated sheaths showing large patches of disease which passed right through and were continued into the sheaths lying below.

Arecanuts are even less liable to attack than coconuts. The largest number found in any one village within a limited period was 17 at Billakurru in the second half of 1907. No experiments have been carried out to investigate the susceptibility of this species to attack. Arecanut gardens are not common and the disease in this palm is of little importance.

Palms of all ages are liable to the disease. The majority of cases are mature trees. In many cases young trees from three to five years old, growing under larger diseased trees, become attacked. It is the custom to plant the nuts along the bunds or dry banks

between the paddy fields, and the seedlings grow up beneath the older palms which line these bunds. In such cases it is probable that the vertical drip of water during rain carries down the spores to the young plants below. This would only occur in the cases in which the living fungus grows exposed to the rain. Further, successful infection would only occur if the spores reach a suitable part of the palm, such as an exposed inner leaf-sheath. Hence there is usually far less disease amongst the seedlings and young trees than in those which are large enough to be regularly climbed for leaves. Isolated young palms not growing near larger ones are seldom attacked ; isolated mature ones almost as often as those in clumps.

The intensity of the disease varies enormously in different places. Four hundred palmyras were found dead or dying in a single acre in one of the lankas close to where the disease is believed to have first appeared in the district. It was calculated that from 50 to 75 per cent. of all the palms within a mile of the village of Kolanka had succumbed by the end of 1907. In one place along the bank of the canal near this village the mortality increased from between 5 and 10 per cent. in August 1905, to between 60 and 70 per cent. in March 1907. In some fields of Ainavilli three-quarters of the palmyras were infected in June 1907. In one clump in this village 180 out of 236, in another 107 out of 140 had died. Of course, these are extreme cases, but there are many villages where it appears probable that not a fourth of the palms will soon be left unless the disease is checked.

The length of time taken to kill a tree can only be determined if the moment of first attack is known, and requires also the fixing of an arbitrary moment of death. In so large an organism as a mature palm, death does not occur all at once, excepting possibly under such circumstances as when a tree is struck by lightning. Ordinarily, death occurs "by inches," and when the apical bud and even all the leaves are killed, the stem and roots may still maintain their vitality for some time. Two periods may be selected as indicating the "death" of the palm in bud-rot. The first is

when the central shoot, formed of the innermost, partly expanded leaves, withers and dies. In the vast majority of cases this indicates that the heart of the leaf-bud has been reached and the apical point, which is the single locality in palms at which new leaves are formed, has been killed. Except in rare cases, to be described below, withering of the central shoot is a fatal symptom in palms ; no new leaves are produced ; the older ones gradually dry up ; no new food is manufactured, and though the tree lives for a time on food-reserves stored in the older tissues, these become eventually exhausted and total death ensues. A second period which may be taken as indicating ''death'' is when every leaf has withered and fallen and nothing is left but a bare pole. Long before this has happened all chance of recovery has disappeared, and it is therefore more satisfactory to select the first-mentioned indication in calculating the duration of the disease.

An experiment to determine this was carried out in 1908. Three rather young palms were inoculated on one of the outer leaf-sheaths, that selected being, as usual in the inoculations, not the outermost hard, dry sheath, but the clean moist one just below. They were kept under observation and after a little over five months the central shoot in two was found to be withering. The third still showed no external symptom and, as observations ceased soon after, its subsequent fate is not known. The other two were cut down and examined. One had 25 fully formed leaf-sheaths inside that inoculated, the other 30. In the first the infection, starting from the point inoculated, had penetrated twelve sheaths in immediate contact one beneath another. After the 12th sheath there appeared to be several quite free from infection spots. Then those in the centre of the crown, and the base of the central shoot itself, were severely attacked, the latter being reduced to a putrid mass Passing through several of the disease spots on the outer sheaths were the tunnels of the rhinoceros beetle, and these were continued on through some of the unmarked sheaths to the base of the central shoot. Either the parasite was carried in by the beetle, or the course taken by it from the 12th sheath

through several of those below escaped detection. The apical bud was involved in the rot at the heart of the crown and the tree was, therefore, beyond recovery.

In the second tree 10 sheaths were penetrated from that first inoculated. Then as before there were several apparently quite sound, while the centre of the bud was a rotten mass. Here again there were beetle tunnels running from the outer spots to the centre and opening a route for the parasite. In this case also the palm was beyond hope of recovery.

Hence in rather over five months the disease had penetrated about half of the radius of the bud (the outer sheaths are thicker than the inner) and had then jumped in some less direct fashion to the centre. Even granting that it grows at the same rate throughout, and is not assisted by insects, it should kill the tree in ten months. It probably grows much faster in the softer inner tissues than towards the outside, so that the time may be correspondingly reduced. Beetles are extremely common in diseased trees and may be attracted to them ; these may lead to further shortening of the time by carrying the parasite rapidly through several sheaths. This is what appears to have happened in the two trees experimented upon. Therefore it seems safe to conclude that the disease is capable of killing moderately sized palms in from five to ten months from the date of first attack.

The period which elapses between the death of the central shoot and the loss of all the leaves of the crown is much longer. The central shoot of an outwardly healthy palmyra was noticed to become slightly pallid and less rigid than before between the 17th and 19th of December 1907. Sixteen days later the central shoot was quite withered and four of the inner leaves were yellowing. After twelve days more another leaf had turned yellow. Another tree observed in March 1907 when the central shoot had withered, was found nine months after to have lost only some of the central leaves, those towards the outside being still unwithered and firmly attached to the crown. Usually many months elapse before all

the leaves wither, and even then they take some time to fall away from the crown. From many enquiries it appears that three years or more may pass from the time when the ceutral shoot dries up until all the leaves have fallen.

Similarly, the ryots stated that a coconut may be reduced from a fine, healthy, bearing tree to a bare pole in four years. It takes about three months for one of the central leaves to fall after it begins to wither. It has been noticed that in rainy or cold weather the leaves die and fall more slowly than during the hot dry parts of the year.

Recovery of diseased trees after the central shoot or even the greater part of the crown has withered sometimes occurs. In most of the cases observed this is due to the growing point having escaped injury. The parasite, passing in from the outer sheaths, may reach the central shoot at a point above its base and therefore well above the growing point. Usually when this occurs, subsequent extension down the central shoot takes place and the apical bud is destroyed. In some cases, however, the growth remains horizontal and the central shoot is cut across and breaks off. This is often accompanied by the death of several or even all of the expanded leaves of the crown. The appearance presented by such trees varies with the severity of the first attack. In extreme cases the whole of the expanded leaves of the crown are shed and the palm reduced to a bare pole, the top of which is flattened or even hollowed into a cup. From this rises, as if separately planted in this position, a small shoot of a few, usually much reduced and distorted, leaves, with their leaf-bases forming a narrow funnel, at the bottom of which is the growing point. One very characteristic case seen was that of a young palmyra only three feet high, which had lost all its older leaves, leaving the apex of the stem fully exposed and concave. From the centre of the depression rose the new shoot, consisting of three expanded small leaves and a fine central shoot of folded leaf-blades. In another large tree the same conditions were found, but the new shoot, seen from below, appeared to arise laterally from near the margin of the cup-shaped depression and its

leaves were much distorted. The lateral position may have been due to the new shoot pushing out before the older dead leaves had been cast, and being forced by these out of the direct line of growth. In other cases the older leaves of one side only were killed, those of the opposite side remaining healthy. The central shoot had broken off and had been replaced by a new shoot of small crumpled green leaves. Nearly all the instances so far noticed in which a new shoot has developed to replace that destroyed by the disease, have succumbed to a second attack in a comparatively brief period. In no case as yet observed has the new growth progressed sufficiently to bear fruit and in only one to form a crown of ordinary size. This is one of the indications that the parasite is capable of passing into a dormant condition and renewing its growth at a later period.

V.—Seasonal prevalence.

Much attention has been given to an attempt to ascertain the seasonal prevalence of the disease. The cultivators and tappers in several places declare that the deaths are most numerous from December to February, and least in the hot months, March to June. A study of the figures from the villages of Amalapur Taluk in which there are records of the number of new attacks observed periodically does not bear out the first part of this statement. It leaves no doubt, however, that the deaths are least numerous between February and July.

The following table shows the rainfall at Rajahmundry at the head of the Delta and the relative humidity at 8 A.M. at Masulipatam on the sea at the southern limit of the affected area :—

Average monthly rainfall in inches at Rajahmundry.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
0·14	0·25	0·32	0·91	2·93	4·84	7·09	6·67	7·15	6·45	1·98	0·15

AVERAGE MONTHLY RELATIVE HUMIDITY AT 8 A.M. AT MASULIPATAM.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
86·4	85·6	83·1	80·7	76·1	77·1	78·8	82·7	84·2	83·6	81·7	80·8

The coldest period of the year is from December to February. This is also the period of least rainfall, but the relative humidity is high in the two last months, there is a heavy condensation of dew at night, and the mornings are damp and foggy. From April to July is the period of highest temperature and lowest relative humidity, and although there is a moderate and increasing rainfall, there is little dew and the mornings are clear and bright. Temperature, rainfall and relative humidity all fall in November, after the receding monsoon, and before the cold weather fogs appear.

The following tables give figures of deaths amongst the palms observed periodically in a number of villages of Amalapur Taluk in 1907 and the first half of 1908. This period coincides with the origin of a widespread attempt to limit the ravages of the disease. It is probable that, as a result of these operations, the deaths towards the end of the period were less numerous than they would otherwise have been. This does not, however, invalidate the conclusions to be drawn from the figures, as the higher figure in many cases follows the lower.

I. Villages showing most deaths when humidity is high and least when it is low.

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
Gangalakurru	Feb. 10th to Sept. 2nd '07.	153	Sept. 3rd '07 to Feb. 8th '08.	345	Feb. 9th to June 19th '08.	89
Bandarulanka	Jan. 31st to Sept. 8th '07.	68	Sept. 9th '07 to Feb. 23rd '08.	125	Feb. 24th to June 15th '08.	68
Nadupudi ...	Feb. 10th to Aug. 6th '07.	1	Aug. 7th '07 to Feb. 1st '08.	88	Feb. 2nd to June 26th '08.	21
Amalapur ...	Jan. to June '07.	631	June '07 to Jan. '08.	1,053	Jan. to July '08.	235

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
Vanne Chinta-lapudi.	Jan. 29th to Aug. 18th '07.	62	Aug. 19th '07 to Feb. 26th '08.	153		
Irusamanda ...	July 20th '07 to Feb. 29th '08.	104	March 1st to July 4th '08.	16		
Vadapalem ...	Sept. 9th '07 to Jan. 21st '08.	91	Jan. 22nd to Sept. 3rd '08.	13		
Mosalapalli ...	Feb. 10th to Aug. 9th '07.	30	Aug. 10th '07 to Feb. 3rd '08.	80		
Nalamilli and Janupalli.	March 31st to Aug. 5th '07.	35	Aug. 6th '07 to Feb. 11th '08.	117		
Palagummi ...	March 8th to Aug. 7th '07.	18	Aug. 8th '07 to Feb. 2nd '08.	133		
Avidi ...	Sept. 7th '07 to Jan. 23rd '08.	797	Jan. 24th to July 2nd '08.	85		

Within the period of greatest mortality there is sometimes evidence of a secondary period of diminished virulence. This varies somewhat in time but occurs after the south-west monsoon has ceased. The subsequent recrudescence is probably responsible for the idea already mentioned that the greatest mortality occurs in the cold weather.

II. Villages showing in diminution after the Monsoon and a recrudescence in the cold months.

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
Anatavaram ...	July 29th to Sept. 17th '07.	267	Sept. 18th to Nov. 9th '07.	58	Nov. 10th '07 to Jan. 23rd '08.	164		
Siripalli ...	May 3rd to Oct. 20th '07.	173	Oct. 21st to Dec. 22nd '07.	16	Dec. 23rd '07 to Feb. 1st '08.	61		
Magam ...	April 22nd to Sept. 17th '07.	624	Sept. 18th to Dec. 18th '07.	96	Dec. 19th '07 to Jan. 28th '08.	143		
Nedunur ...	Aug. 28th to Oct. 7th '07.	312	Oct. 8th to 30th '07.	33	Oct. 31st to Dec. 14th '07.	246		
Vilasa ...	May 15th to Oct. 13th '07.	554	Oct. 14th to Dec. 30th '07.	78	Dec. 31st '07 to Feb. 4th '08.	162		
Isakapudi and Potavaram.	May 9th to Aug. 28th '07.	362	Aug. 28th to Nov. 25th '07.	93	Nov. 26th '07 to Mar. 10th '08.	238		
A. Vemavaram	June 4th to Aug. 13th '07.	123	Aug. 14th to Oct. 22nd '07.	192	Oct. 23rd '07 to Jan. 3rd '08.	39	Jan. 4th to Feb. 8th '08.	191

This secondary diminution after the rains is not by any means universal, and there is no indication of a cold weather recrudescence in the following cases, where the maximum mortality was at the end of the monsoon.

III. Villages in which the maximum mortality occurred at or near the end of the Monsoon.

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
Bhatnavilli ...	April 10th to Aug. 23rd '07.	64	Aug. 24th to Oct. 24th '07.	193	Oct. 25th '07 to Feb. 2nd '08.	80
Mungonda ...	May 12th to Aug. 25th '07.	37	Aug. 26th to Dec. 4th '07.	116	Dec. 5th '07 to March 12th '08.	59

In a good many villages the deaths appeared to occur fairly regularly between August and February as the following show :—

IV. Villages in which the deaths are evenly distributed between August and February.

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
Uppalaguptam	Aug. 28th to Nov. 13th '07.	81	Nov. 14th '07 to Jan. 7th '08.	60	Jan. 8th to Feb. 6th '08.	53
Narendrapuram	June 10th to Aug. 28th '07.	118	Aug. 29th '07 to Jan. 9th '08.	244	Jan. 10th to March 4th '08.	117
Modekurru ...	June 6th to Sept. 1st '07.	245	Sept. 2nd to Dec. 8th '07.	192	Dec. 9th '07 to April 25th '08.	188
Machavaram ..	Feb. 1st to July 3rd '07.	341	July 4th to Oct. 12th '07.	561	Oct. 13th '07 to Feb. 20th '08.	568
Udumudi ..	Aug. 30th to Dec. 13th '07.	42	Dec. 14th '07 to Feb. 26th '08.	57		
Polivela ...	Oct. 2nd to Nov. 22nd '07.	718	Nov, 23rd '07 to Jan. 28th '08.	969		
Tondavaram ...	July 21st to Oct. 31st '07.	56	Nov. 1st '07 to Feb. 7th '08.	65		

In a few cases the figures show little evidence of a seasonal period of maximum intensity throughout the year.

V. *Villages which do not show any marked period of maximum intensity.*

Village.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.	Period.	Deaths.
K. Pedapudi ..	April 28th to Sept. 3rd '07.	200	Sept. 4th to Nov. 30th '07.	126	Dec. 1st '07 to Feb. 11th '08.	114	Feb. 11th to June 26th '08.	164
Mukkamala ..	May 11th to July 21st 07.	20	July 22nd to Oct. 9th '07.	49	Oct. 10th '07 to Feb. 28th '08.	22	Feb. 29th to May 29th '08.	30
Pulletikurru ...	June 1st to July 17th '07.	58	July 18th to Oct. 3rd '07.	405	Oct. 4th to Dec. 21st '07.	266	Dec. 22nd '07 to May 5th '08.	334
Chiratapudi ..	May 15th to Aug. 19th '07.	157	Aug. 20th to Nov. 22nd '07.	100	Nov. 23rd '07 to March 26th '08.	180	March 27th to April 28th '08.	133

To sum up the question of seasonal prevalence it is clear that, with few exceptions, the deaths are more numerous in the villages of Amalapur Taluk in the months from August to February, than from March to July. This is in close relation with the relative humidity of the two periods, and applies equally well to the other affected Taluks. There is a less close relation with the rainfall. In the monsoon, especially in its second half, the mortality appears to reach its maximum, but it is high also in the cold weather months of heavy dew and ground fogs, when there is usually little rain. A distinct diminution in the mortality is observable in a good many instances after the cessation of the monsoon, followed by the cold weather recrudescence. This is not general, since a few cases can be quoted where no diminution after the rains occurred. Still it was sufficiently marked to have attracted attention from the supervisors in charge of the work of checking the spread of the disease.

VI.—Symptoms.

As already mentioned, the disease is usually confined in its earlier stages to the large fleshy leaf-sheaths which encircle the apex of the palm, just below the expanded crown of leaves. The outermost

of these, exposed to the air, are usually brown and dry and are moreover partially hidden by the cut bases of older leaves, and in coconuts by loose fibrous layers. Hence it is not possible to detect the spots on the outer sheaths in standing trees, and as a rule the first indication visible without felling the tree is the withering of the central shoot or of one of the expanded leaves. In the great majority of cases it is the central shoot that withers first. This is undoubtedly because the heart of the bud, which consists of the young unexpanded leaves and their bases, is very soft and full of sap, while the sheaths towards the outside are progressively harder and less juicy. Hence the parasite grows through these from the outside without, as a rule, much lateral expansion, and forms on them only isolated spots or patches, not large enough to cause the leaves above to die from stoppage of food supplies and loss of support. As soon as it reaches the young soft tissues of the unexpanded leaves it spreads with great rapidity and soon destroys the centre of the bud. The cluster of partially expanded leaves in the centre of the crown is next affected, and in this stage the presence of the disease can be detected from below. Less often the first leaf to show morbid changes visible from below is one of those fully expanded. It is merely a question of accidental circumstances favouring the growth of the parasite in particular places. The affected leaves first turn pale and then wither, becoming dry and yellowish brown in ten or twelve days.

Besides the leaf-sheaths the parasite also occurs on the leaf-blades in certain cases, and even on the petioles. One of the figures on plate III shows the characters of the attack on the blade. From the symmetrical nature of the spots on the segments of the leaf, as well as from several cases actually observed, it is clear that the attack occurs while the young blade is still folded within the bud. In some of these cases the tissues above the spots die and fall away, and the blade appears as if cut across at the level of the disease. Very few cases of attack on the petiole have been seen. In one an expanded leaf was bent and hanging down from about the centre of the petiole, where a large, soft, brown and sunken spot passed right

through its thickness. In another there was a spot affecting only about half the breadth of the petiole, the rest and the blade above being still green and healthy.

The apex of the stem is sometimes also affected. In one case observed the inner part of the crown was destroyed and the young wood below the diseased leaf-bases was soft and discoloured with pink and brown patches. These contained living mycelium of the parasite.

The spots on the leaf-sheaths vary much in size, from only just visible to six inches or more across. In the inner sheaths they are white at first, becoming brown or reddish later on. On the outer sheaths they may eventually be black. A very early result of the attack is the collapse of affected cells, which leads to the spots being sunk below the level of the surface of the rest of the sheath (see photograph on plate III). The margin of the depression is usually bounded by a raised rim. The early spots are dry and hard and may either be quite free from any external parasitic growth or covered with a white mycelial web. Later on, particularly in the soft heart of the bud, the diseased areas are invaded by numbers of saprophytic organisms, bacteria, moulds and insect larvæ, and the whole is converted into a foul-smelling rotten mass.

On the leaf-blades the spots are usually smaller than on the sheaths, not often exceeding an inch in diameter on individual segments. They are straw-coloured in the centre and bounded by a broad dark-brown margin.

The flow of toddy from diseased palmyras is checked soon after the death of the central shoot. In a case observed a palm was marked for tapping by the Abkari officers in January 1908, after the toddy drawer had climbed and carefully examined it and pronounced it healthy. The central shoot was found withered in the first week of April, but the tree was still being tapped. The quantity of juice obtained was only about one-half that from healthy trees, and the quality was bad. It is the practice to mix the juice from such trees with that from healthy trees, as it is otherwise unpalatable.

In coconuts the fruit is affected. None of those formed after the symptoms of the disease are visible externally, develop properly; they drop one by one while immature. Those formed somewhat earlier may ripen, but are often of inferior quality.

VII.—Description of the Parasite.

Pythium palmivorum belongs to a genus of the most primitive group of the fungi, the Phycomycetes or alga-like fungi. The characters of this genus have been sufficiently described in a previous number[1] of this series, and need not be considered in detail here. It is composed partly of aquatic and partly of terrestrial forms, several of which are parasitic on other plants. The terrestrial forms are nearly all soil-dwellers, two only, the present species and P. Indigoferæ Butl., inhabiting the aerial parts of plants. The description of P. palmivorum, previously published, requires to be amplified as a result of further examination.

The body of the fungus consists of branching threads or "hyphæ" forming in the aggregate a web or "mycelium," which may be entirely buried in the palm tissues or may be partly superficial on the surface of the leaf-sheaths, where it frequently develops so as to form a thick white felt over the disease-spots.

The hyphæ, which are very irregular, measure on an average 5μ ($\frac{5}{1,000}$ millimetre) within the tissues but are often larger, especially in the superficial felted mass where they may be up to 8μ. They are continuous hollow threads, not being divided by cross-walls, except in rare cases, particularly near where the organs of propagation are formed. Within the tissues they occur in the intercellular spaces, and also force their way between adjacent cells, becoming irregularly compressed and contorted in so doing. They are nourished exclusively from the living cells of the host-plant, into which they send fine prolongations known as "haustoria" or suckers.

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1 Butler, E. J. An account of the genus Pythium and some Chytridiaceæ. Memoirs of the Dept. of Agric. in India, Vol. I, No. 5, 1907.

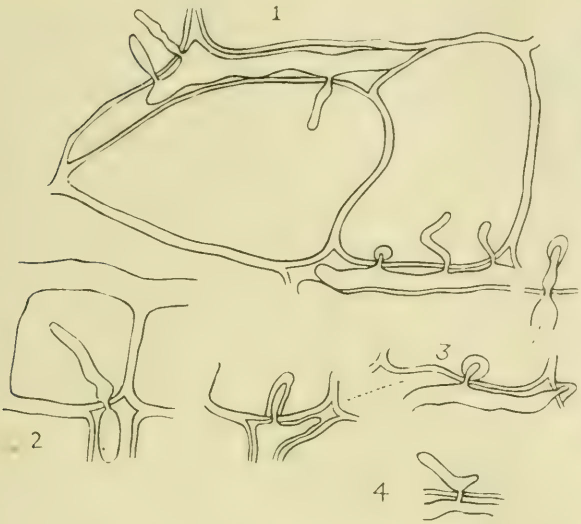
The ends of the young germ-tubes from germinating spores possess the power of boring through the wall of the sporangium. Penetration is effected by the exudation of a solvent liquid, which is almost certainly, from the analogy of other known cases, a cellulose-dissolving enzyme, from the tip of the germ-tube. This was clearly observed in cases in which zoospores germinated within the sporangium, as in those figured in plate IV, fig. 15. Figs. 15*a* and *b* show a spore which failed to escape through the mouth of the sporangium, and after swarming for a time within it, came to rest and surrounded itself with a wall as usual. A couple of hours later it had germinated and the germ-tube had reached the opposite wall of the sporangium. The apex of the germ-tube now swelled up and became closely appressed to the wall. A vacuole occupied its tip. Some time after, it was noticed that an area of the wall considerably larger than that in contact with the tip of the germ-tube had undergone an alteration, which was visibl' in profile as a gelatinous swelling in which the sharp double contour of the rest of the wall was lost (fig. 15*a*), and from above (surface view) as a light, extremely transparent spot (fig. 15*b*). The swollen portion of the wall was clearer than the rest. Actual penetration was not observed in this case, but fig. 15*c* shows the ultimate condition from another similar case. The same power of penetrating cell walls is possessed by the haustoria, which are able to enter the parenchymatous tissue cells, but are not found in those of the vascular bundles. The ordinary vegetative hyphæ are, however, unable to enter the host cells, but grow exclusively between them ; in other words, their tips do not excrete a cytase.

When a leaf is first infected, the infection may arise from germinating spores or from vegetative mycelium. The latter is what occurs when a leaf-sheath is infected from another in contact with it, as happens regularly during the progress of the disease towards the centre of the crown. In this case it is probable that penetration occurs through the stomata, which are numerous on the outer surfaces of the leaf-sheaths. In tracing the disease inwards through

successive leaf-sheaths, it is easy to find spots in the innermost layers where the parasite has only penetrated a portion of the sheath thickness, the spot being visible on the outside but not on the inside of the sheath. Sections through these show the hyphæ passing through the stomata. Some of these appear to be hyphæ of entry, though the fact is extremely difficult to prove. Others are hyphæ of exit, as is shown by branching taking place just outside the stoma. Hence it is evident that the parasite, after invading a sheath from the outside, may send back branches through the stomata to the outer surface, and it is this fact which makes it difficult to be certain that entry occurs along the same road. In a few cases the mode of entry or exit shown in plate V, fig. 11*a*, where a hypha engages in the thickness of the cuticle and passes along the vertical walls of the epidermal cells, was seen, but whether such hyphæ were going in or coming out could not be decided. The rarity of these cases, compared with those in which hyphæ pass through the stomata, makes it very probable that the latter is the ordinary mode both of entry and of exit.

When the first infection is from zoospores no evidence is available as to the route followed. As already mentioned, the germ-tube can bore through cellulose walls, but this does not imply that it can penetrate the cuticle. The fact that the internal mycelium is purely intercellular does not preclude the possibility of entry directly across the epidermal cells, for in Phytophthora Colocasiæ Racib., a common parasite in India, the germ-tubes penetrate the leaf frequently in this manner, though below the epidermis they are strictly intercellular. The only reason for believing that zoosporal infection in Pythium palmivorum occurs through the stomatic openings is that, in many sections examined, no case was seen of hyphæ passing across the epidermal cells, though some of the spots sectioned had resulted from inoculation with zoospores. Still some cases were seen in which hyphæ occupied the cavities of the epidermal cells as shown in plate V, fig. 11*b*, and this seems to show that these cells offer less resistance to the entry of the parasite than those of the parenchyma.

Excepting the bundles and the bands of sclerenchyma, which are numerous, the parasite is found in all parts of the leaf, reaching to the bundle sheaths on the one hand and to the inner walls of the epidermis on the other. The haustoria arise from any part of the hyphæ and are numerous. They are found in both parenchyma and epidermis and are straight or curved finger-shaped processes, which rarely branch.



Haustoria of Pythium palmivorum.
1. In thin-walled parenchyma. 2. In an epidermal cell. 3. Club and button-shaped haustoria with cellulose cap. 4. Branched haustorium.

After the internal mycelium has become copious and has accumulated a sufficient store of food from the contents of the host-cells, branches from it emerge through the stomata to the surface. When the next underlying sheath is closely in contact, it may be infected by these hyphæ without the formation of any visible superficial mycelium. Often, however, there is sufficient space between the sheaths (especially when the attacked area becomes depressed) to allow of the formation of a considerable mass of white web-like mycelium, which is one of the distinctive characters of the species. No other species of Pythium known to me, nor any of the allied genus Phytophthora, forms such a dense mycelium as the originator of palm bud-rot. Under these hyphal masses it is common to find hyphæ emerging from the majority of the stomata. The superficial hyphæ differ but little from those within the leaf, except that they are sometimes considerably thicker (plate IV, figs. 1 and 2). On them and not on the internal mycelium, the reproductive organs

of the parasite arise. These are of two types, sporangia and resting conidia.

The sporangia are formed terminally on the main branches of the mycelium or on short or long stalks borne laterally on these. They are produced in great numbers in favourable conditions, such as when a piece of leaf-sheath with a spot containing vigorous internal mycelium is incubated in a moist atmosphere for 24 hours. Then a dense growth of hyphæ occurs from the stomata, the hyphæ being irregularly branched and usually terminating in sporangia, while others may arise on lateral branches lower down (plate IV, fig. 3). The superficial growth in these cases is woolly, from free branching of the emergent hyphæ, and is partly erect, partly creeping. Sporiferous hyphæ may stand up nearly $\frac{1}{4}$ inch from the surface of the leaf. In watch-glass cultures from young infected leaves, long threads consisting of a number of hyphæ have sometimes extended from the leaf to the sides of the glass, and on these lateral sporangia are common. Old mycelial webs immersed in water for 24 hours often give rise to numerous sporangia on short stalks arising from any part of the mycelium (plate IV, fig. 4). As is the case generally in Pythium, definite conidiophores distinct from the rest of the mycelium, such as are found in most of the Peronosporaceæ, do not occur; the sporangia are formed on the tips of ordinary hyphæ or on lateral branches from them.

The sporangia are very variable in size and shape. In the previous description they are given as 50 by 35μ on an average (extremes 38 to 70 by 33 to 42), but smaller ones than this are not uncommon in poor cultures. The shape is typically piriform, the attachment being by the broad end. Irregular shapes, such as those figured in plate IV, fig. 5, are common, and the attachment is sometimes lateral (plate V, fig. 10*a*). When ripe, the narrow end is always papillate, the papilla varying from a small knob to a protrusion $\frac{1}{4}$ the diameter of the sporangium; it is broader than is customary in the genus.

Germination of the sporangia takes place very rapidly when sown in water, within half an hour under favourable conditions. Four

types of germination occur, which though distinct enough in appearance, are all modifications of the one process. The most characteristic, though by no means the most common, is that which is practically universal in the genus Pythium and which is, as pointed out in the general account of the genus previously referred to, the only absolute mark of distinction of this genus from Phytophthora. In this case the apex of the papilla swells up into a very thin gelatinous vesicle into which the protoplasm of the sporangium passes in a uniform granular mass. Within the vesicle it segments to form a number of zoospores, which develop cilia and move ever more vigorously in the confined space, until the vesicle wall ruptures and the spores swim off in all directions (plate IV, figs. 6 and 7). In some cultures prolonged search was necessary to find instances of this type of germination; in others it was quite common. On the whole it is less frequent in the cooler months of the year than that next to be described.

This is simply an incomplete form of the last, in which the vesicle is either not formed at all, the apex of the papilla dissolving, or if formed, ruptures almost immediately. Segmentation into zoospores occurs within the sporangium, and is complete or nearly complete before the papilla opens. As soon as an opening forms, the protoplasm streams out and breaks up at once into free swimming zoospores (plate IV, fig. 8). Owing to the pressure of the mass within the sporangium it is not possible to distinguish the individual zoospores before escape, but it is evident that they must be fully formed before the rupture of the papilla since they separate at once after escape, and also because as soon as pressure is reduced by the extrusion of part of the sporangial protoplasm, the remainder may segment while still inside and emerge as fully formed mature zoospores. This is the type of zoospore formation habitually met in Phytophthora, and in several cases the palm parasite would have been taken for a Phytophthora, had not prolonged search revealed an occasional instance of the first type of discharge. Intermediate types between the two are sometimes found. Thus in one case about three-quarters of the protoplasm emerged in a mass surrounded by a vesicle,

which then dissolved, and the mass at once broke up into individual zoospores, as did the remaining one-quarter still within the sporangium at the moment of rupture of the vesicle. Sometimes the vesicle is formed in the ordinary way but the zoospores are almost mature when they leave the sporangium and the vesicle early dissolves to liberate them.

The third mode of germination is a regression on the last. The zoospores mature within the sporangium and when the papilla opens are unable, from one cause or another, to escape. After a variable period of free movement within the sporangium they come to rest *in situ,* round off, become clothed with a wall and germinate by germ-tubes which pierce the sporangial wall (plate IV, fig. 9). Here also intermediate cases between this and the last type occur. Sometimes a portion of the protoplasm escapes in a mass and breaks up at once into zoospores which swim away in the water. Blocking of the tube of exit from any cause then prevents the remainder from escaping, and this segments within the sporangium to form zoospores which ultimately germinate *in situ* as just described. Even when complete segmentation within the sporangium occurs, some of the resulting zoospores may creep out through the opening while others fail to escape.

The last type of germination is that in which zoospore formation is entirely suppressed, and the unopened sporangium germinates by putting out one or several germ-tubes in the manner of a conidium. Conclusive evidence was given in the previous account of the genus to show that this is merely a further reduction on the zoosporal type. It is one of the main adaptations to a terrestrial life which the semi-aquatic Phycomycetes have developed in the process of establishing themselves on land. Successful dissemination by zoospores requires the presence of water in bulk, and is unsatisfactory in species which are only intermittently irrigated. Germination by germ-tubes merely requires a moist atmosphere, and has entirely replaced the older zoospore method in the higher fungi. In Pythium the transition is clearly seen, and it is almost equally maintained in Phytophthora, all the species of which still preserve the

zoosporal method, while most can also germinate by germ-tubes. In the higher Peronosporaceæ the formation of zoospores gradually disappears and direct germination becomes the rule. Plate IV, figs. 10 and 11, show direct germination of the sporangia of Pythium palmivorum. In many cases the germ-tube is single and arises from the papilla at the apex of the sporangium (fig. 10). In others a number of germ-tubes arise scattered over the surface (fig. 11). Usually the growth of the germ-tubes is limited, and secondary sporangia are early formed at their apices and those of their branches (fig. 10 *b. c. d.*).

The zoospores are of the ordinary Pythium type, and measure from 8 to 10 μ after they come to rest and assume a spherical shape. They germinate rapidly (within an hour) by one or sometimes two germ-tubes, which may grow to a considerable length and branch (plate IV, fig. 12). Sometimes they fail to germinate and break up into a granular mass (plate IV, fig. 13). In a few cases two or more spores remain united after leaving the sporangium. These double zoospores are marked by their large size, and instead of becoming spherical at the end of their period of swarming, assume an oval or irregular shape, and are surrounded by a single wall (plate IV, fig. 14). Germination in these cases is quite normal. In one instance the whole contents of the sporangium escaped in a mass and moved about with an irregular jerky motion, eventually coming to rest and forming a common wall. Germination was not seen.

The second spore form is that which was termed an oospore in the previous description. Further examination has shown that it is not a sexual product and is not contained in an oogonium, but is a distinct "resting" variety of conidium. At certain periods of the year, *e.g.*, in the hot dry weather in March, only this spore form has been found. In other cases it has been found on the same mycelium as the sporangia, and there is no doubt of its being a stage of Pythium palmivorum. The resting spores are spherical, thick-walled, often yellowish when old and are formed singly at the ends of usually large hyphæ (plate V). Intercalar ones have occasionally been observed (plate V, fig. 7). They measure from 25 to 40 μ

in diameter, the wall being up to 4 μ thick. Irregular shapes are sometimes met with (plate V, figs. 8 and 9).

The stalk hypha is sometimes exactly like those of the vegetative mycelium, sometimes variously dilated and irregularly branched (plate V, figs. 2 to 5). In many cases it is septate some distance below the spore, the appearance resembling the hypogynal antheridia found in P. de Baryanum, P. Artotrogus and other members of the genus (plate V, figs. 1, 2 and 5). In other cases branches from the stalk hyphæ or from neighbouring ones closely encircled the spore (plate V, figs. 2 and 4), and it was these appearances, as well as the general resemblance to an oospore, which led to its being described previously as a sexual spore. However, many cases have since been seen in which it was formed terminally on a simple unseptate stalk entirely free from adjacent hyphæ and with no trace of anything that could be construed as an antheridium (plate V, fig. 6). This, together with the absence of any differentiation of the contents into an oospore lying within an oogonium, quite precludes its being construed as a sexual formation, and it must be considered as a much more highly developed equivalent of the resting conidia of P. de Baryanum. The germination has been previously described and is invariably by a germ-tube, which may branch and always bears terminal sporangia after a short growth (plate V, fig. 10). The period during which these spores preserve their vitality is not known, but is likely to be at least some months.

No trace of true oospores has been discovered during the period that the parasite has been under observation. A sufficient number of cases has been examined to make it probable that if they occur they must be rare and are not likely to be of any practical importance in the life of the species.

From the observations made at different times of the year it has been noticed that sporangia are usually found on the attacked leaves only at the periods of considerable rainfall or heavy dews. They were found in June, July and August without much difficulty, less often in September. In March none could be found in one locality where a rather thorough search was made. Resting conidia are less

common in the rainy period, but very numerous in the hot dry months. Sterile webs of mycelium occur at all times of the year and may often be induced to form sporangia by placing in water for 24 hours. More often than not it is in this form only that the fungus exists on the palm sheaths excepting immediately after heavy rain or dew.

Numerous attempts were made to cultivate the parasite artificially without success. The media used were boiled slabs of palmyra leaf-sheath, plantain, potato, bread, boiled prune and grape juice and sugar solution, and boiled flies. Zoospores, sporangia and mycelium were used for separate inoculations. In no case did the slightest growth of Pythium palmivorum take place. The fungus is probably an obligate parasite as are nearly all parasites that feed exclusively by haustoria and do not send their hyphæ into the cells. This fact has been noted by Matruchot and Molliard for the genus Phytophthora[1], and is perhaps of wide application.

VIII.—Inoculations.

The following is a detailed account of some of the successful inoculations carried out. Owing to the locality of the disease being about 1,000 miles by rail from his head-quarters, only series III below was carried out by the writer personally. The others were done under his directions and in most cases controlled by subsequent microscopic examination of spirit specimens. Series I was done by his assistants, Mr. S. N. Mitra and Babu R. Sen ; Series II, V and VI by Mr. Sundararaman, Mycological Assistant to the Government Botanist, Madras ; Series IV by Messrs. Mitra and Sundararaman conjointly.

I. The material used for inoculation was young living mycelium, bearing sporangia and resting spores. It was obtained from the surface of fresh clean spots on an inner sheath of a recently attacked palmyra, and was microscopically pure. The trees inoculated

[1] Matruchot L. et M. Molliard. Sur le Phytophthora infestans. Annales Mycologici, Vol. 1, p. 543, 1903. H. Klebahn has, however, cultivated on artificial media his Phytophthora Syringæ which is exclusively intercellular except its haustoria. (Krankheiten des Flieders, Berlin, 1909.)

were five palmyras from five to seven feet in height (to the base of the crown), two of which were in low land under shade and three in a drier situation, unshaded.

The inoculations were made by removing the outer leaf-sheaths until a white clean sheath was exposed, and applying a portion of the material to the surface. The surface of the sheath was not artificially sterilized, but was probably sterile, as the sheaths fit so closely over one another that there is ordinarily no cavity left between. The instruments used were flamed. The method does not differ in any way from that commonly adopted in dealing with obligate parasites such as the rusts and mildews, as in the absence of artificial cultivation of the parasite it is not possible to secure rigorously sterile conditions.[1] After inoculation the last removed leaf-sheath was replaced in position and firmly bound in place. The wrappings were watered at intervals for two days to prevent premature drying of the material.

On the 4th day after inoculation one of the trees was examined. A discoloured patch was visible at the point where the material had been placed. A day later the infected area was marked off from the rest of the sheath by a marginal line, inside which were several isolated spots of a deeper brown than the rest. Two days later the other trees were examined, and a depressed area, marked by brown spots of different sizes and surrounded by a raised edge along which ran a reddish-brown bounding line, was found to occur in all, at the place where the inoculations were made. The outer sheaths that had been replaced over the infected ones had also become attacked and from this time onward the point inoculated could be detected, without unfastening the wrappings, by means of the spots which penetrated them. By the 8th day one sheath was found completely penetrated, the depressed area being larger on the inside than on the outside. This was seen by lifting the free edge of the sheath without removing

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[1] The nearest approach to such conditions has been obtained by the late Professor Marshall Ward working with grass rusts. The ingenious method adopted is described in the Proceedings of the Royal Society, Vol. LXIX, No. 458, 1902, p. 451, but is obviously inapplicable to plants of the size of those under consideration.

it from the tree. Next day a surface growth of mycelium had appeared near the edges of some of the spots. On the 11th day the sheaths were removed one by one from the inoculated trees. In each case the parasite had passed completely through three sheaths (including that inoculated) and had entered the fourth sheath but not reached its inner surface. In two of the unshaded trees insects and moulds had collected on the spots and a wet rot had developed. In the other three the spots were dry and permeated only by the mycelium of Pythium palmivorum. Microscopic examination showed that the characters of the mycelium and its relations in regard to the host cells were exactly as described above. Sporangia and resting spores were borne on the surface mycelium on the second and third sheaths.

II. Two young trees were inoculated in the same manner as in the last experiment. On the 10th day the free edges of the inoculated sheaths were pulled back so as to see those next below. In one the next sheath was only slightly affected and no further progress occurred, probably because the premature disturbance of the first sheath caused drying of that below. In the other, large patches covered with a superficial mycelium were found on the next sheath below the point inoculated. This sheath was also pulled back and was found with small spots on its inner surface where penetration had occurred. One small unsunken spot occurred on the surface of the third sheath. In this case growth of the parasite continued and five days later the sheaths were cut away one by one. Two more sheaths were found penetrated by the parasite, and the next sheath below was marked by a small spot on its outer surface. In 15 days, therefore, the parasite had passed through five sheaths and infected the sixth.

III. The material used was obtained from a recently infected unopened leaf in the heart of the bud of a diseased Palmyra, which was placed for 12 hours in a covered sterile watch-glass with a few drops of boiled water. A good growth of mycelium extended to the sides of the glass and bore quantities of sporangia. Some of this was picked off on sterile needles and sown in sterile water ; in about

half an hour a copious zoospore formation took place. The zoospores, without any mycelium, were washed off into a sterile covered watch-glass and used for the inoculations. The material in this case was likely to be absolutely pure, since it was obtained from an aerial growth consisting exclusively of Pythium palmivorum, and since some of it, used to inoculate sterile culture tubes of palmyra slabs, gave no growth of foreign moulds.

The inoculations were made on three palmyras varying from 6 to 12 feet in height exactly as described above, except that drops of water bearing only zoospores were used.

On the 4th day one of the trees was examined and a slight discolouration without any depression found at the inoculated point. On the 6th day all were examined and showed brownish discoloured patches at the seat of inoculation, the colour being much deeper than in the one examined two days earlier. A copious exudation of gum was taking place from the inoculated patches. Two days later all the trees showed the marginal boundary line, and two were developing isolated dark brown spots on the discoloured area. By the 10th day the affected area was distinctly depressed and the margin raised up. On this day one of the inoculated sheaths was removed and that next below was found slightly discoloured, where the parasite had reached it after penetrating through the first sheath. After 4 weeks all the sheaths were removed and it was found that 3, 4 and 6 sheaths respectively (including that inoculated) had been attacked, in the line towards the centre of the bud. In one case a lateral extension of 8 inches was found on the sheath next below that inoculated.

IV. The material used was a fresh growth of mycelium bearing ripe sporangia. It was obtained by placing pieces of a young palmyra leaf-sheath, cut as aseptically as possible and with superficial mycelium, for about 18 hours in a sterilized Petri dish. By this time the previously sterile mycelium had given off numbers of fertile hyphæ with sporangia ready to germinate on the addition of water.

The trees were two palmyras and a coconut about 8 feet high, and the inoculations were made as before. After 8 days the inoculated sheaths of two of the trees were examined. In the coconut one large brown spot, about ½ inch in diameter, and two lightly coloured smaller spots were found on the inoculated area. In one of the palmyras there was a large irregular slightly discoloured blotch. The wrappings were again replaced and not removed until a month from the time of inoculation. Little progress had occurred in the coconut palm, the large spot being now much sunken but scarcely larger than when seen before and it had not penetrated the sheath. In the palmyras the inoculated sheaths had been penetrated and those next below infected but not completely penetrated.

V. The material used was a drop of water containing zoospores from a slide on which sporangia had discharged.

The inoculation was made by opening the folds of a very young leaf in the apical shoot of a young palmyra, pouring in the drop, closing the folds and securing them by a thread.

After 14 days the inoculated leaf was cut and examined, and brown patches were found extending through about 10 of the folds. These were sectioned and found to contain hyphæ of Pythium palmivorum.

VI. The material was a small mass of mycelium from the superficial web of Pythium palmivorum from a diseased palm.

The inoculations were made as in the last experiment, on the still folded leaf in the bud of two young palmyras.

The inoculated leaves were cut and examined after 28 and 30 days respectively. Brown spots extended from the inoculated place through three or four folds, and on sectioning hyphæ were found passing through the stomata.

The above cases show that the disease can be produced by artificial inoculation. In the first experiment the number of sheaths

penetrated was three and-a-half in eleven days; in the second, 5 were penetrated in 15 days. Both these were done in the period of heavy monsoon rains. In the third, carried out in late September in bright sunny weather at the end of the south-west monsoon, there were only 3, 4 and 6 sheaths respectively, penetrated in 28 days in the three trees inoculated. In the 4th, which extended from November 10th to December 10th, the progress was still slower. The experiment quoted on page 238 showed that in two trees 10 and 12 sheaths had been penetrated in the period from March 24th to September 10th, which includes the driest and wettest months of the year. Hence it would appear that the progress of infection may be rapid in the rains but gets slower as the amount of rain diminishes and the temperature falls in the cold weather. It is probable that in the last quoted experiment, most of the extension took place subsequent to the onset of the monsoon in June, as there is a great deal of observational evidence to show that little occurs ordinarily in March, April and May.

IX.—Dormant condition of the Parasite.

The difference in the rate of progress of the disease in inoculated trees leads us directly to the consideration of cases which suggest that the parasite may pass into a dormant condition for a greater or less period and resume growth again. It was frequently observed during the earlier period of the campaign undertaken to destroy all diseased trees in the affected area, that fresh deaths continued to recur after a locality had been cleared of dead and dying palms. At first these were believed to be new infections conveyed in some manner unknown. Then it was noticed that there was a difference in the distribution of these cases as compared with outbreaks which were undoubtedly due to fresh infections, as when a village became attacked for the first time. In the latter case the deaths were in groups or often in one small part of a village only, indicating spread from one or a few early attacked trees. The deaths in villages that had been one or more times cleared of all outwardly diseased trees occurred scattered throughout the cleared area. In Amalapur

village such scattered cases continued to recur with the greatest persistence. In two small areas kept under continuous observation which had been cleared of a large number of diseased trees in November 1906, five subsequent inspections up to September 1908 yielded fresh cases. It was impossible that outwardly diseased trees could have escaped cutting on these occasions, since the plots were close to the road through the village which was frequently traversed by those in charge of the work. Similarly outside infection was scarcely to be thought of, for the whole village, as well as those adjoining, had been very thoroughly and repeatedly worked over, being the head-quarters of the Taluk where the campaign was prosecuted with the greatest energy. Examination of several of these cases showed that the outer leaf-sheaths bore unmistakable evidence of previous infection, the old brown spots on the outer sheaths being split and dried up. The sheaths of at least two years' leaf supply often remain attached to the tree, and there was every reason to suppose that some of the spots seen on this and other occasions on the outer sheaths may have been two years old. It is now believed that such old spots may serve for a considerable time to re-start an active phase of the disease. This is probably brought about through the tardy germination of resting spores, which have several times been found in the dried mycelial webs on the surface of old spots. The mycelial growth resulting from the germination of the resting spores is small and soon terminated by the formation of one or two sporangia. The spores from these would settle on the sheaths in contact and might succeed in penetrating them, whereas from their small number and entangled position in the old sheaths there would be little likelihood of the sporangia being carried to other palms before germination.

Several cases of arrested penetration have been seen. In one, a previously healthy palm was found with fresh spots on the outer sheaths on the 6th July. On October 23rd it was cut and spots found extending through 4 sheaths, after which the spread had apparently stopped. In another, some 10 sheaths had been penetrated but all the spots were old and the innermost appeared to have

ceased to grow some considerable time previously. A cut tree was found to have succumbed to a second attack, the first having penetrated nearly to the bud, killing the outer leaves, and then stopped. Subsequently 5 healthy leaves had been put out and a recommencement occurred in the rains, and these and the central bud were killed. In this case it was calculated that the dormant period had lasted four or five months.

A number of observers have noticed that palms which show symmetrical spots of disease on the expanded leaf segments always die sooner or later. It has previously been explained that these spots are caused by penetration of the tube of leaf-sheaths at a position above the growing point, the central bud of folded leaves being reached through its enclosing sheaths. The subsequent death of the crown, occurring sometimes months afterwards, would be readily explained by assuming that extension recommences from the spots on the inner sheaths and ultimately reaches the growing point.

All the above affords considerable ground for believing that the parasite can pass into a dormant condition actually within the bud, and can recommence activity at a later date, progressing until the growing point becomes involved and death ensues.

X.—Measures for controlling the disease.

Suggestions for an organised attempt to stamp out the disease in the infected area were made to the Government of Madras in April 1906, and are given almost in full in the paper on Palm Diseases in the Agricultural Journal of India, October 1906, referred to above. As a result, a sum of Rs. 5,000 was provided for a trial of the measures proposed in a limited area. These were sufficiently promising to justify larger proposals, which were given effect to in the middle of 1907. Since that time a large campaign, having as its objects to limit the disease to the area already invaded and to stamp it out within that area, has been in continuous operation. Since January 1910 it is believed that every part of the infected area is being systematically dealt with.

The trial measures were confined to three firkas, one in each of the taluks of Amalapur, Ramachendrapur and Cocanada. A young Indian Mycological Assistant, Mr. S. Sundararaman, from the Government Botanist's Office, Madras, was placed in charge of the work. He was provided with three Revenue Inspectors, subordinate Indian officials of the Revenue Department, one being posted on special duty to each of the selected firkas. The first step in the work was the issue of a circular to all the villages in the firka, calling for a return of the number of affected trees within each village area. Each tree counted by the village officers and village servants was marked with lime. The Revenue Inspector then arranged to visit in turn every village reporting the presence of the disease. On his arrival a fresh examination was made, and a number of professional palm climbers (toddy drawers or "Idigas," of whom a large number live in the Delta) sufficient to carry out the work required, were hired. Some of these were provided with small axes and employed in cutting away the tops of diseased palms. Others were engaged in applying Bordeaux mixture to the leaf-sheaths of all palms within a radius of about 25 yards from those diseased. At the end of the day's work coolies were employed to gather together and burn the cut crowns. As a rule no difficulty was encountered in obtaining fuel for burning the crowns, as their own leaves usually afford sufficient for the purpose. The workers quickly became expert, and with a little experience it was found that a good man would cut off the tops of about 15 palms or apply Bordeaux mixture to about 35 in a day. The axes were provided by Government, and the Bordeaux mixture required for each day's work was prepared the evening before by the Revenue Inspector. It was served out as required, after thorough stirring, into small pots which, with a bunch of rags for applying it to the sheaths, was hung to the back of the climber's belt. Each tree took about a pint for effective covering of the sheaths. It was found that the Inspector could supervise the work of about 20 climbers, but it was not always easy to recruit the full number required in the village under treatment, and later on climbers were frequently imported from other villages in the district.

The data obtained as a result of the work in the Coringa Firka of Cocanada Taluk in three months, from December 1906 to March 1907, are given below. The results in the other firkas were comparable. In Coringa Firka there are 35 Government villages of which about 20 reported the presence of the disease. During the first three months of the operations about 12,000 palms were cut and about 45,000 treated with Bordeaux mixture. The cost, including pay of supervising establishment, wages of coolies and cost of materials but excluding pay of the Mycological Assistant, was about Rs. 900 (£60). It was estimated that the cost of treating the palms with Bordeaux mixture, including all charges except supervision, was one pie ($\frac{1}{12}$ anna) per tree, which accounts for Rs. 234-6, leaving Rs. 665-10 for cost of cutting 12,000 palms and supervising charges. This gives about ·9 anna per tree cut.

In reviewing these trial operations it was evident in the first place that no permanent good could be expected from them,[1] owing to their small scale and the continued inflow of infective matter from the surrounding untreated area. They, however, gave very valuable indications of the practical difficulties to be encountered, afforded a reliable basis for estimating the cost of any further extension of the work and showed several directions in which improvement could be effected.

The whole of a firka was found to be too large an area for one party to work through. Since at the time of first treating a village, a number of palms were certain to have been infected so recently as to show no outward symptoms and were sure to remain undetected, it was evident that subsequent visits would have to be made to discover and destroy these when they developed sufficiently to be visible from the ground. As already pointed out the trees are not dangerous to their neighbours in these early stages, and one or two return visits of this nature would, it was anticipated, be sufficient to account for all. The parties required for these secondary operations, and the time taken in each village in carrying them out, would

[1] The writer was not consulted when they were planned.

not, it was estimated, be considerable. It was suggested that the first return visit should be made a month from the completion of the first operations, and three or four months later any subsequent infections should be removed. As Coringa Firka took altogether nearly four months for one party to work through once, it was clear that further staff was required for the secondary operations.

The chief difficulty was found to be that of securing that a really careful search should be made for diseased trees. The village officers were very unreliable in this respect and it was difficult to impress on the executive staff the vital importance of not letting a single diseased tree escape. It was, and has been up to date, necessary to struggle constantly with the tendency of the Revenue Inspectors to settle down in a village, cut the trees in its immediate vicinity, and leave the surrounding country unexplored.

Little attempt was made in the beginning to secure the co-operation of the villagers themselves. From the middle of 1907 considerable efforts were made in this direction. A vernacular pamphlet was distributed broadcast throughout the whole of the infected area, and the permanent staff were constantly urged to use every opportunity for securing independent action. The results were, it must be admitted, most disappointing. Owners of coconut gardens in many places cut out their dead trees, but would not do so as long as there was any chance of getting a crop. Very few palmyras have been cut by the cultivators themselves. The apathy of the Indian cultivator in such matters is too well known to need comment.

It was found advisable to abandon the treatment of healthy palms with Bordeaux mixture. It was thought wise to concentrate all efforts on the cutting out and burning of diseased tops, since this was likely to give the surest results and a larger area was likely to be freed from infective matter in a given time. The chief reason, however, was that the treatment with Bordeaux mixture appealed much more to the imagination of the ryots than the destruction of diseased palms, owing to their natural antipathy to destroying any-

thing that might be conceivably of the least use to them afterwards. This might have led to very serious consequences by diverting their attention from the really essential part of the measures taken.

It was recommended that the work should be concentrated in Amalapur Taluk at first. This Taluk comprises five firkas and bordered on non-infected tracts and on the sea for a considerable portion of its periphery. For the rest it was separated from infected parts of Ramachendrapur and Nagaram Taluks by large branches of the Godavari, across which reinfection was not likely to be frequent. The area of the Taluk is 506 square miles, of which about four-fifths were infected in 1907.

Accordingly an enlarged campaign was commenced in Amalapur Taluk in June 1907. The executive staff consisted of eight Revenue Inspectors and Assistant Revenue Inspectors. The general control of the staff was entrusted to Mr. A. A. Ferguson, an Assistant Collector of the Indian Civil Service. In addition to Mr. Sundararaman, three Supervisors were employed, two, Mr. S. N. Mitra and Babu R. Sen, from the Mycological Laboratory, Pusa, and one, Agricultural Inspector Balakrishna Murti, from the Madras Department of Agriculture. Later in the year Revenue Inspector K. Lakshmana Rao, who proved exceptionally capable, was promoted to the position of Supervisor and Messrs. Mitra and Sen returned to Pusa. The Supervisors were each assigned a definite area within which they were expected to travel about, check the work of the working parties and call attention to any neglected cases or any recrudescence of the disease in villages already worked over. They were also empowered in cases of urgency to employ labour independently for cutting out diseased trees.

The difficulties encountered during the operations were numerous, but were generally surmounted successfully, where this was possible, by the efforts of the staff. One of the chief, however, has always been present to a greater or less extent ; this is the difficulty of securing permanency in the staff itself. Every Department

in India is normally short-handed and any new call for a staff outside of ordinary work at once introduces complications. The Agricultural Department, which should naturally have taken charge of the entire work, was of new creation, its organisation was incomplete and it was impossible to find the staff required for the work. Even the Supervisors at first appointed, had to be taken off after some time owing to urgent demands for their services elsewhere. Mr. Ferguson had much other work connected with the District administration. The Revenue Inspectors were continually being transferred, as they are all borne on one common establishment and a vacancy in a higher grade may lead to a number of minor promotions and changes. It was most trying to find that a man who had got well acquainted with the work was suddenly transferred and a raw new-comer put in charge of one of the ranges. I wish to acknowledge invaluable aid in smoothing difficulties received from the Collector of Godavari, Mr. J. A. Cumming, I.C.S.

The recruitment of the staff of palm climbers and coolies was often difficult, particularly at the busy seasons of the agricultural year. Sometimes this was got over by importing labour from outside. Eventually the daily pay was raised from 4 to 5 annas, a rate slightly above current labour rates, and this was on the whole effective.

It was sometimes difficult to get individual diseased trees cut. Old cases are reputed dangerous to climb as they may be hollow and rotten ; very thin ones are difficult to climb. These were generally cut at the ground level, but cutting from the base was not generally practised because of the great hardness of the wood at this part. Trees on which banyans grow (not uncommon in the Delta) are held sacred and will not usually be cut by the people of the village in which they occur. Usually, however, outsiders have no scruples in this respect, and the villagers have no objection to a man from another village being imported to cut such trees.

It required continual watchfulness to prevent the leaves of diseased crowns being carried away for fuel and thatch. A certain

amount of infective matter has no doubt been preserved from burning on this account, but the staff were continually impressed with the importance of securing the destruction of the entire crown. The danger of dissemination rapidly disappears when the cut leaves are exposed to the heat of the sun, as is the case with most that are used in the villages. In rainy weather or where supervision was slack, the cut crowns were sometimes left to accumulate for some days. This was a serious fault and every effort was made to check it. The two important difficulties all through have been, however, the difficulty of obtaining the co-operation of the ryots, and the difficulty of securing a reasonably permanent staff.

By December 1907 the whole of the infected area of Amalapur Taluk had been worked over, and all the old cases cut out. The first return visit had been paid in most villages and the second was in progress. This set free a portion of the staff, and the work was accordingly extended to Ramachendrapur Taluk by the beginning of 1908. A considerable recrudescence in Amalapur Taluk in January and February 1908 detained about half the staff south of the Gautami until the hot weather. By the 1st April, 1908, the returns showed that 177,000 palms had been cut in Amalapur Taluk since the beginning of the operations, and probably over a quarter of a million in the whole area. The total cost incurred up to date had been about Rs. 18,000 (£1,200) including pay of establishment except the supervisors.

In April 1908 Mr. Ferguson was transferred, and as his successor Mr. W. K. Green, Special Deputy Collector, did not join until July, the work suffered through want of supervision. Supervisor Balakrishna Murti was taken off in July and Sundararaman in October. Three parties remained on in Amalapur, and were fully occupied in dealing with the effects of the wide-spread recrudescence which had occurred in the early months of the year. The greater part of the staff was concentrated in Ramachendrapur where a large area had to be dealt with.

In October 1908 Mr. Green introduced a new system for carrying on the operations. The experience in Amalapur had shown, especially in the period from January to July 1908, that it was not possible with the staff available to ensure that new cases were cut out sufficiently rapidly to prevent them becoming dangerous to surrounding healthy trees. So long as it was believed that the disease progressed rapidly and continuously within the palm crown from the time of infection to the death of the tree, the previous arrangements appeared to afford sufficient safeguards against the danger of leaving any considerable number of diseased trees uncut long enough to enable them to infect others. The simultaneous occurrence of a large number of deaths early in 1908, together with other observations referred to on a preceding page, led to a strong probability about this time, which afterwards became practically a certainty, that the disease frequently does not progress continuously, but becomes arrested after penetrating some way into the bud. It is probable that arrest occurs in a considerable number of trees over a large area at about the same time, from some common cause such as temperature or dryness of the air. In the same way when conditions of growth again become favourable, general recrudescence may occur, and a large number of deaths, too large to be rapidly dealt with by a few travelling parties, appear simultaneously.

It became necessary, therefore, to endeavour to devise a system under which simultaneous operations over a large area would be possible. This Mr. Green did by transferring the onus of removing dead trees in each village from the special staff to the village officers. This relieved the whole of the staff of 8 Revenue Inspectors from all work, except that of inspecting each village, checking the trees reported cut by the village officers and making the necessary payments for hire of palm climbers and coolies.

Under this system, which is still in force, the village officers of every village reporting the disease are required to submit monthly progress reports showing the number of trees cut in each village during the month. They also maintain registers showing the survey

numbers[1] in which diseased trees occurred and the number in each. When a Revenue Inspector comes round (an effort is made to inspect each village once a month) the register is produced and a certain percentage of the entries checked by an actual visit to the survey numbers indicated. Payment is then made at a fixed rate of $\frac{3}{4}$ anna per tree cut to the village officer.

Delays naturally occurred in the introduction of the new system. A circular had to be issued to all the village officers, but as these are sometimes illiterate and often careless, its purport had to be explained by the inspecting staff. By January 1909 most of Ramachendrapur and Cocanada Taluks had begun regular cutting and the village officers were reported to be co-operating fairly well. In Amalapur, however, they were slow to perform their share of work and Rajahmundry and Nagaram were worse. In March 1909 only 260 villages out of 566 in the infected Taluks of Godavari District sent in reports, in April, 327.

From April 1st, 1908, to March 31st, 1909, about 140,000 palms were cut out in the Godavari District at a total cost of Rs. 14,109 (£940).

In the face of considerable difficulties Mr. Green continued to effect an improvement in the work of the village officers. He was given powers of reprimand and of inflicting small fines directly in cases where the village officers were persistently remiss in seeing that trees were cut. This gradually told and in August 1909, 432 villages out of 566 in the infected Taluks of Godavari submitted reports. By December the number had risen to 518 and by the beginning of this year cutting was progressing practically simultaneously over the whole of the infected area in Godavari. The total number

[1] For land record and revenue purposes each field in a village receives a number on the village map. It is therefore easy to find any particular field and check the trees cut. Later on the stems of cut trees were consecutively numbered, to avoid any risk of the same tree being entered and paid for more than once.

of trees cut from April 1st, 1909, to March 31st, 1910, was 84,107. The cost was not available at the time of writing.

The period during which operations have been in progress in the different parts of the Godavari up to the beginning of 1910 may be roughly summarised as follows:—Amalapur and parts of Ramachendrapur and Cocanada a little over three years; the rest of Ramachendrapur over two years and of Cocanada about 18 months; Peddapur about two years; Rajahmundry about 18 months; Nagaram one year. At the same time it must be understood that equal activity has not been shown in all districts. Outlying ones have often neglected the work, and the inspecting tours of the writer and of the controlling staff have proved that several, perhaps many, villages have allowed dead trees to accumulate for months.

In the following table, which gives the figures of cut trees paid for month by month from December 1908 to January 1910, the figures do not accurately indicate new cases of disease since the preceding month. In some villages the accumulations of several months may be cut out in one effort as a result of actual or threatened punishment, and will all appear in one month's return. In others, through slack inspection or connivance of the inspecting staff, the cutting of a large number of trees may be spread over several months. Cases were seen by the writer in Nagaram Taluk in February 1910 where, although some of the diseased palms in a village had been recently cut, others that were of some months' duration had been left standing and would go to swell the totals of succeeding months. Hence though the table gives a general, it does not give an exact, statement of the number of fresh infections in the reporting villages each month. It is, of course, to be borne in mind when considering the monthly totals for the whole area, that the number of villages reporting increased month by month to more than double the original figure. This does not imply that new villages were infected, but merely that an increasing number took up the work.

Statement showing the number of cut trees paid for by Revenue Inspectors monthly from December 1908 to January 1910 inclusive, in the Godavari District.

Months.		Nagaram Taluk (51 villages).		Amalapur Taluk (171 villages).		Ramachendrapur Taluk (117 villages).		Cocanada Taluk (105 villages).		Rajahmundry Taluk (91 villages).		Peddapur Taluk (31 villages).		Total of the six Taluks (566 villages).	
		No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	No. of villages which sent in reports.	No. of trees paid for.	Villages.	Trees paid for.
December,	1908	37	*	38	3,029	71	3,603	19	2,011	31	294	13	Included in the figures for Ramachendrapur Taluk.	209	8,937
January,	1909	15	183	41	4,780	34	4,224	15	4,872	68	31	5		178	14,090
February,	,,	48	432	21	3,987	70	3,484	7	2,629	65	0	3		214	10,532
March,	,,	48	168	14	4,531	115	2,455	26	64	57	66	...		260	7,284
April,	,,	51	215	10	3,609	101	2,241	74	2,469	65	0	26		327	8,534
May,	,,	17	215	52	1,149	73	2,639	59	1,449	24	184	5		230	5,636
June,	,,	8	97	76	3,531	58	1,185	49	1,290	13	50	11		215	6,153
July,	,,	6	† 0	91	1,488	56	1,739	34	599	13	0	31		231	3,826
August,	,,	51	† 0	81	1,932	117	1,531	90	879	67	135	26	10	432	4,487
September,	,,	49	† 0	87	814	117	3,038	96	952	62	136	19	...	430	4,940
October,	,,	51	14	77	2,662	115	4,261	96	928	64	57	31	132	434	8,054
November,	,,	51	208	110	4,093	117	3,711	102	1,452	57	97	30	...	467	9,561
December,	,,	51	153	146	4,672	117	2,353	105	1,386	69	76	30	112	518	8,752
January,	1910	51	56	148	3,275	117	2,475	102	1,882	73	43	28	...	519	7,731
															108,517

* Figure not available.

† No Revenue Inspector available.

The account of the operations so far refers exclusively to the Godavari District. The existence of the disease in the Kistna District, across the Vasishta Godavari from Amalapur, was reported

by Mr. Ferguson in March 1908. Under the Indian administrative system each district forms a separate unit, the officers of which have no standing in the next district. It was accordingly necessary to move the Government of Madras to extend the operations into the Kistna District. The Collector of Kistna, however, reported in December 1908 that the attack in his district was due to a beetle and not to a fungus. The writer received very definite information early in 1909 that the disease was undoubtedly the same in both districts and was rapidly extending in Kistna, and in conjunction with Mr. Green submitted proposals for the staff and expenditure required to deal with it. These proposals were sanctioned late in the year and Mr. Green placed in charge of the work in both districts. It was not until January 1910 that the organisation was complete and cutting operations actually commenced.

The total staff employed in January 1910 was as follows :—

Godavari District.

4	Revenue Inspectors	on Rs.	40/	per mensem.
5	,,	,, ,,	30/	,, ,,
9	Peons	,, ,,	7/	,, ,,

Kistna District.

5	Revenue Inspectors	on Rs.	40/	per mensem.
4	,,	,, ,,	30/	,, ,,
9	Peons	,, ,,	7/	,, ,,

Special Deputy Collector's Staff.

1	Clerk	on Rs.	20/	per mensem.
1	Head peon	,, ,,	9/	,, ,,
3	Peons	,, ,,	7/	,, ,,

In the Kistna District a considerable number of villages are infected in Tanaku and Narsapur Taluks which adjoin Amalapur and Nagaram Taluks of the Godavari. Yernagudem Taluk is slightly affected, and there is at least one severe outbreak in Bunder Taluk near Masulipatam. The disease is also reported with some doubt from Gudivada Taluk. The total area affected is probably small as compared to that in the Godavari. It is impossible at present

to gauge the importance of the extension to the south. The infection of Tanaku, Narsapur and Yernagudem is clearly an extension from the infected Taluks of the Godavari and the total area affected is not believed to be large. There is a great jump however from these Taluks to Bunder and Gudivada, and the intervening country will have to be gone through very carefully to search for some continuous line of extension. There is a considerable coastal traffic between the Godavari and Masulipatam and the possibility of infective material having been conveyed by human agency by sea must be taken into account. The rapidity with which the disease has spread, when once it passed south of the Godavari River and out of the area where control measures were in progress, is testimony that the writer's first estimates of its dangerous possibilities were not exaggerated.

It is now necessary to review the effect of the operations on the spread of the disease. The first fact that stands out is that since the end of 1908 there has been no increase in the infected area in the Godavari District, excepting the small area at Katavaram of reinfection from Yernagudem across the river in the Kistna District, referred to on page 229. The exact limits of the area infected to the north and east have been well known since early in 1908 and there can be no doubt on this point. This check is not due to any scarcity of palms, for northwards from the Godavari there is a great area of palm country extending into Vizagapatam and to the base of the Eastern Ghâts. Taken in conjunction with the extension which has been steadily progressing in Kistna where no control measures were in force this result must be attributed to the operations. It was not until after the middle of 1908 that active measures were in force along the whole of the northern and eastern boundaries of the infected area, and the almost immediate check of extension in these directions must be considered as satisfactory.

The second point to be considered is to what extent there has been a diminution in the disease within the area of the operations. At first sight it would appear from the monthly figures of trees cut in the six infected Taluks of the Godavari given on page 274 that the diminution has been slight. As already stated in connection with the

STATEMVILLAGES OF AMALAPUR TALUK, GODAVARI DISTRICT.

NAME OF VILLAGE.	NUMBER OF TREES CUT							AVERAGE PER MONTH.			
Amalapur ..	Between	May	1909	and	January	1910	698	77	for	9	months
Ainavilli ...	,,	April	,,	,,	,,	,,	121	12	,,	10	,,
Nedunur ...	,,	,,	,,	,,	,,	,,	533	53	,,	,,	,,
Avidi	,,	,,	,,	,,	,,	,,	259	26	,,	,,	,,
Billakurru ..	,,	,,	,,	,,	,,	,,	319	32	,,	,,	,,
Polivela ...	,,	,,	,,	,,	December	1909	1,432	159	,,	9	,,
Ryali	,,	May	,,	,,	January	1910	236	26	,,	,,	,,
Vakkalanka ...	,,	April	,,	,,	,,	,,	268	27	,,	10	,,
Vanapalli ...	,,	,,	,,	,,	,,	,,	228	23	,,	,,	,,
Vadapalem ...	,,	,,	,,	,,	,,	,,	43	4	,,	,,	,,
Pedapudi ...	,,	,,	,,	,,	,,	,,	53	5	,,	,,	,,
Nadupudi ...	,,	,,	,,	,,	,,	,,	62	6	,,	,,	,,
Irusamanda ...	,,	,,	,,	,,	,,	,,	126	12	,,	,,	,,
Gangalakurru ...	,,	,,	,,	,,	,,	,,	80	8	,,	,,	,,
Idarapalli ...	,,	,,	,,	,,	,,	,,	30	3	,,	,,	,,
Average per month for all the villages		...						473			

ich it was thought wise to remove at the return visit.

STATEMENT SHOWING THE NUMBER OF TREES CUT BETWEEN CERTAIN PERIODS IN A NUMBER OF VILLAGES OF AMALAPUR TALUK, GODAVARI DISTRICT.

Name of Village.	No. of trees cut at first operation.	Number of trees cut		Average per month.	Number of trees cut		Average per month.
Amalapur ..	3,853*	Between February 1907 and July 1908	1,919	109 for 17½ months	Between May 1909 and January 1910	698	77 for 9 months
Ainavilli ...	6 205	,, July ,, ,, January ,,	355	50 ,, 7 ,,	,, April ,, ,, ,, ,,	121	12 ,, 10 ,,
Nedunur ..	3,232*	,, June ,, ,, June ,,	1,030	86 ,, 12 ,,	,, ,, ,, ,, ,, ,,	533	53 ,, ,, ,,
Avidi	3,906	,, September ,, ,, ,, ,,	88	88 ,, 10 ,,	,, ,, ,, ,, ,, ,,	259	26 ,, ,, ,,
Billakurru ..	6,041	,, August ,, ,, May ,,	936	104 ,, 9 ,,	,, ,, ,, ,, ,, ,,	319	32 ,, ,, ,,
Polivela ...	6,717	,, October ,, ,, January ,,	1,687	421 ,, 4 ,,	,, ,, ,, ,, December 1909	1,432	159 ,, 9 ,,
Ryali	1,548	,, November ,, ,, April ,,	1,234	246 ,, 5 ,,	,, May ,, ,, January 1910	236	26 ,, ,, ,,
Vakkalanka ...	1,420	,, July ,, ,, ,, ,,	392	38 ,, 10⅓ ,,	,, April ,, ,, ,, ,,	268	27 ,, 10 ,,
Vanapalli ..	6,147	,, August ,, ,, May ,,	772	77 ,, 10 ,,	,, ,, ,, ,, ,, ,,	228	23 ,, ,, ,,
Vadapalem ...	775	,, September ,, ,, August ,,	104	9 ,, 12 ,,	,, ,, ,, ,, ,, ,,	43	4 ,, ,, ,,
Pedapudi ...	1 100*	,, May ,, ,, ,, ,,	686	45 ,, 14 ,,	,, ,, ,, ,, ,, ,,	53	5 ,, ,, ,,
Nadupudi ...	159*	,, February ,, ,, ,, ,,	110	6 ,, 16½ ,,	,, ,, ,, ,, ,, ,,	62	6 ,, ,, ,,
Irusumanda ..	882	,, May ,, ,, ,, ,,	329	24 ,, 13½ ,,	,, ,, ,, ,, ,, ,,	126	12 ,, ,, ,,
Gangalakurru ..	565	,, February ,, ,, ,, ,,	587	36 ,, 16½ ,,	,, ,, ,, ,, ,, ,,	80	8 ,, ,, ,,
Idarapalli	267*	,, ,, ,, ,, ,, ,,	90	5 ,, 17 ,,	,, ,, ,, ,, ,, ,,	30	3 ,, ,, ,,
Average per month for all the villages		...	.	1,344	...		473

* Including old cases, mostly bare poles, which had been left standing at the first cutting, but which it was thought wise to remove at the return visit.

table, this is really due to a large number of villages having been persuaded to adopt systematic cutting, and not to any failure of the measures adopted to check the disease. The proof of this is to be found in a consideration of the number of trees cut periodically in the villages where cuttings have been more or less regular for a considerable time. The writer has been unable to find any village which does not show a fall in the number of trees cut periodically, where figures are available from a fairly early period in the campaign.

The villages in the accompanying table illustrate this point. They have been selected absolutely at random, being in fact most of those for which cutting figures up to or later than April 1908 happened to be filed in the Mycological Laboratory, Pusa, with one or two others for which figures were readily available. The total number of palms growing in these villages is so large that the fall in the numbers cut cannot be due to the cutting operations having removed any appreciable proportion of the trees liable to infection.

The above figures show a fall to little more than one-third in the average number of trees cut monthly, the mean interval between the middle of the two periods selected being about 18 months. The fall in Peddapur and Rajahmundry Taluks along the Northern limits of the infected area was more marked and led Mr. Green to report in July 1909 that the disease was practically extirpated from these Taluks. This was an over-sanguine view but still the number of new cases in these two Taluks is now small. Even allowing for the fact that, as stated in the discussion of the figures given in the table on page 274, the monthly figures do not always accurately represent the actual new cases every month, the error applies equally to both periods, and there is no doubt that a marked fall has occurred in the intensity of the disease in the Godavari.

The factor which has prolonged the operations and added enormously to their difficulty is one which was not foreseen when they were first started. This is the existence, which the writer now believes to be unquestionable, of latent infection. How long the parasite may remain dormant within the bud is not known, but there is

evidence to show that the period may be as much as two years. It is not likely to be much more and consequently, if the operations are persevered in, all dormant cases must ultimately declare themselves and be removed. Still it is necessary to realise the fact that it is not possible to exterminate the disease in any locality in even two years, no matter how effectively the work is done. There are many villages in the Godavari where effective cutting has been in progress for little more than a year and these must continue to return a considerable number of cases for some time to come.

The operations have been entirely successful in limiting the disease in the Godavari District to the area previously infected. Now that they have been extended into Kistna, it is fully trusted that they will be equally successful in checking the alarming spread to the South which has been going on for some time in that direction. This alone should fully justify the cost of the operations and their continuation.

It is unfortunately impossible to estimate the number of trees saved from attack within the infected area. If the proportionate number of new cases monthly shown in the preceding table is anything like a true indication, the number saved last year must be very large. In much of Amalapur and Ramachendrapur Taluks the table most probably represents the actual state of affairs, but it cannot be applied to villages where the operations were late in starting. Still the number of trees saved in those parts where the work has been longest in progress must be many thousands, and apart from preventing any extension in the Godavari District it is not unlikely that the value of the palms actually saved within the district, already exceeds the cost of the operations.

PUSA,
The 1*st May* 1910.

E. J. BUTLER.

DESCRIPTION OF THE PLATES.

PLATE I. Views in Godavari with healthy and diseased palmyra palms.

PLATE II. Palm climbers and their work.

PLATE III. Upper figure : a severely diseased clump of palms. Lower figures : spots on leaf-sheath and leaf-blade of palmyra.

PLATE IV. *Pythium palmivorum*, Bull. All figures magnified 320 diameters except when otherwise stated.

Fig. 1. Superficial branched hypha.

,, 2. Superficial mycelial web bearing sporangia.

,, 3. Sporangia on long stalks, from a young culture in a moist atmosphere.

,, 4. Small sporangia, formed laterally on old hyphæ when placed in a moist atmosphere. × 186.

,, 5. Irregularly shaped sporangia.

Figs. 6 & 7. "Pythium" type of germination of the sporangium.

Fig. 8. "Phytopthora" type of germination of the sporangium.

,, 9. Germination of the zoospores within the sporangium.

Figs. 10 & 11. Germination of the sporangia by germ-tubes. 10. *a*, *b* and *c*, single germ-tube from the apical papilla, with early formation of secondary sporangia in *b* and *c*. *d*, single germ-tube laterally from below the papilla. 11. Multiple germ-tubes.

Fig. 12. Germination of the zoospores.

,, 13. Degeneration of a zoospore without germination.

,, 14. Germination of two double zoospores.

,, 15. Penetration of the sporangial wall by germ-tubes of zoospores which have failed to escape from the sporangium. *a* and *b* profile and surface views showing the swollen vacuolate apex of the germ-tube and the swelling and gelatinization of the wall at the point in contact with the apex. *c* penetration effected. × about 400.

PLATE V. Figs. 1 to 10. Resting spores of *Pythium palmivorum*. × 640.

Fig. 1. Resting spores with septate stalk hyphæ.

Figs. 2, 3 & 4. Irregularly swollen and branched stalk hyphæ. In figs. 2 and 4 the branches simulate antheridia.

Fig. 5. A cluster of resting spores on branched swollen stalks.

,, 6. Resting spore on the tip of a long unseptate hypha.

,, 7. Intercalar resting spore.

Figs. 8 & 9. Irregularly shaped resting spores.

Fig. 10. Germination of the resting spores with early formation of secondary sporangia. At *a*, the stalk is inserted laterally.

,, 11. Part of a section of the leaf-sheath of palmyra showing the hyphæ in the tissues and emerging from the stomata. Note at *a*, a hypha imbedded in the cuticle, but whether entering or emerging could not be determined. At *b*, three epidermal cells with hyphæ within them ; elsewhere the hyphæ occur only between the cells, into which they send haustoria. × 600.

Landscape in Godavari with Palmyras.

Palms attacked by Bud-Rot.

A Palm climber.

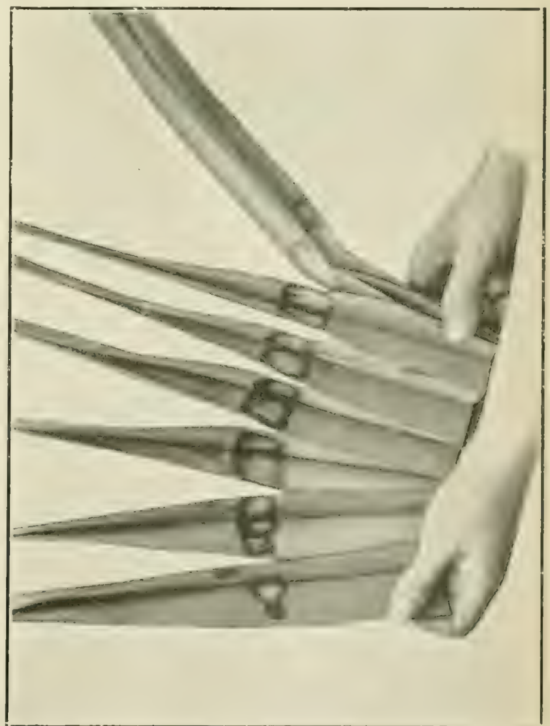
Palm climber at work.

Palm climber at work.

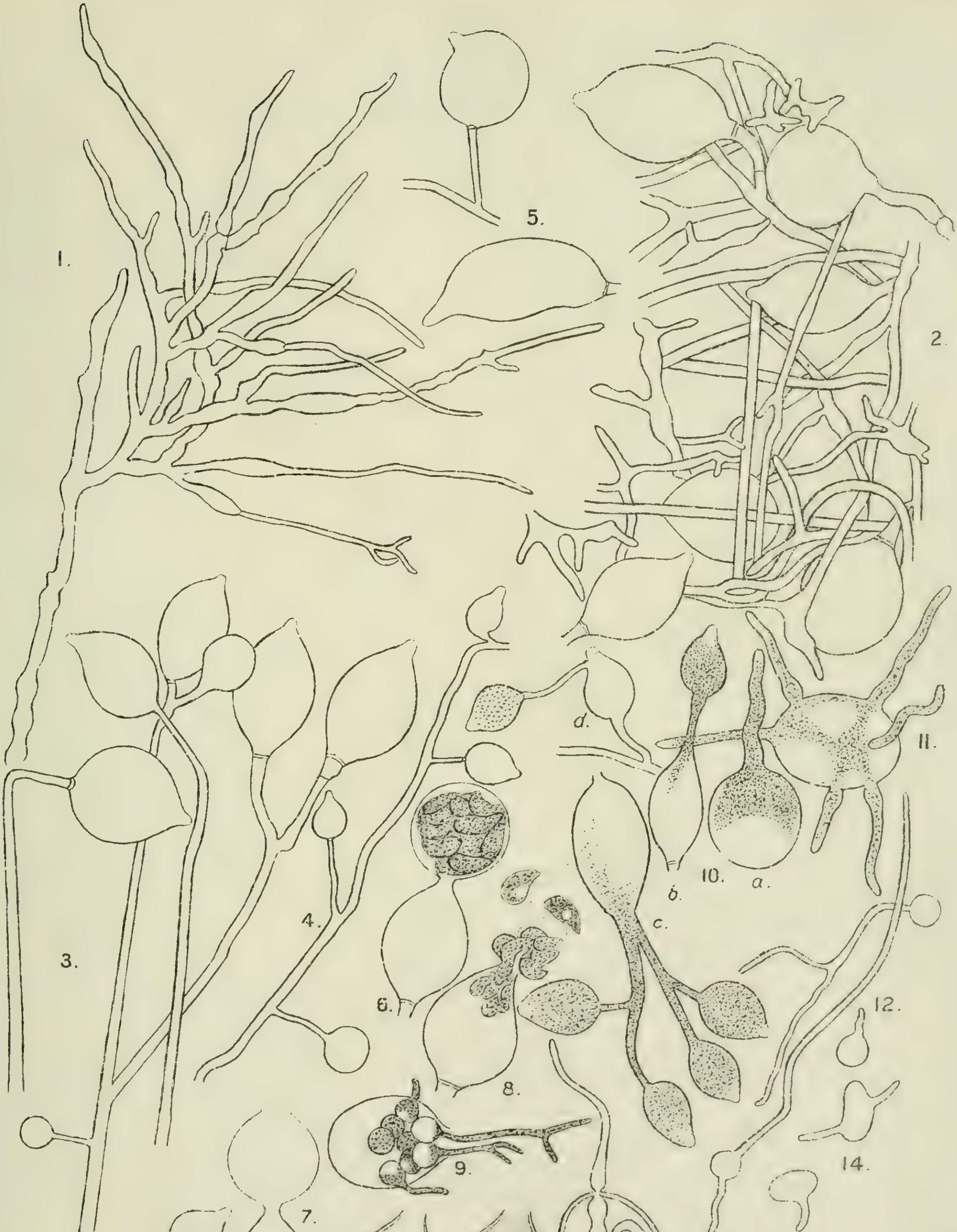
Plate III.

Palms attacked by Bud-Rot.

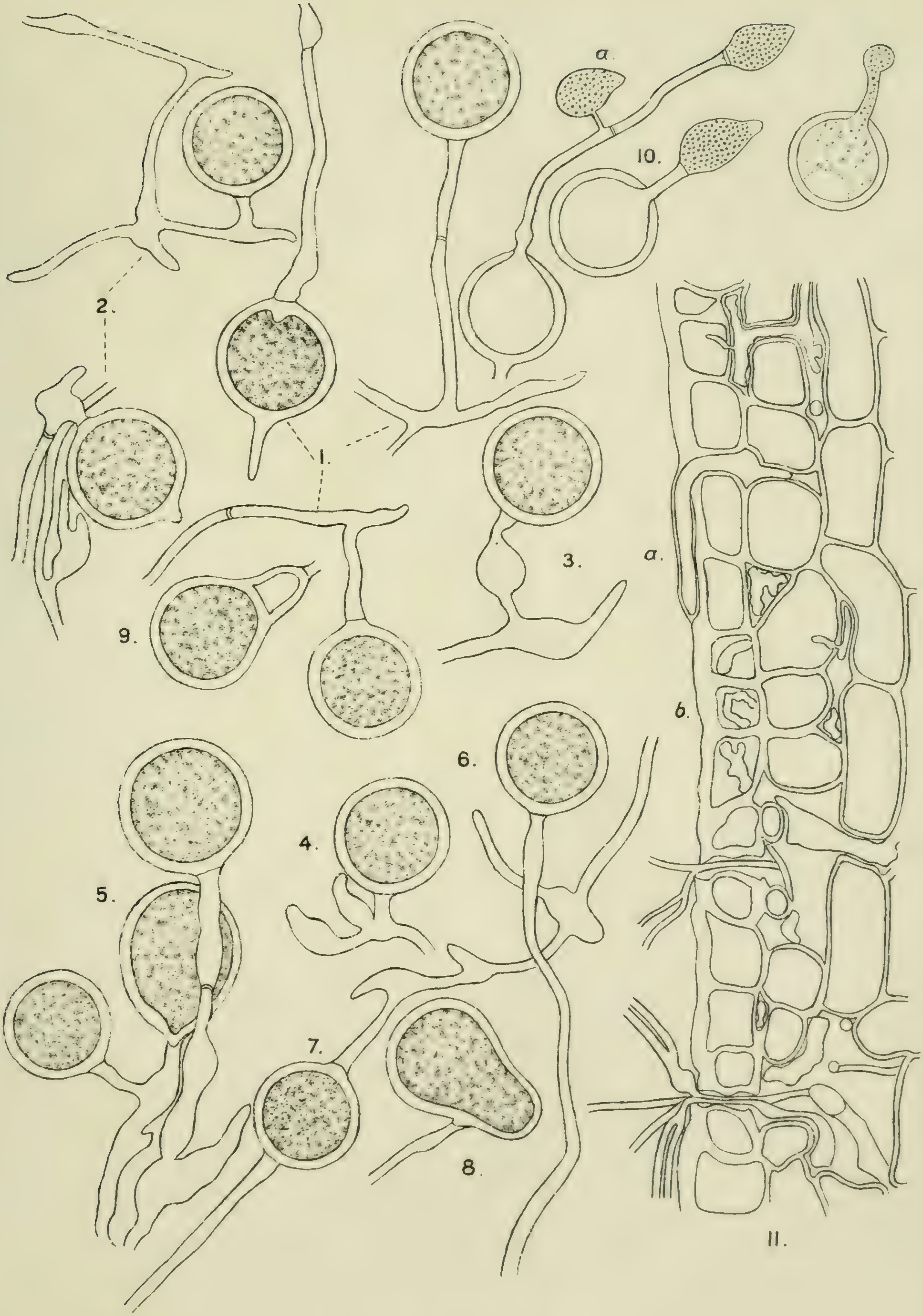
Spots on Leaf-sheath.



Spots on Leaf-blade.



PYTHIUM PALMIVORUM.



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Memoirs of the Department of Agriculture in India

THE ECONOMIC SIGNIFICANCE OF NATURAL CROSS-FERTILIZATION IN INDIA

BY

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Imperial Economic Botanist

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ABDUR RAHMAN KHAN,
Assistant to the Imperial Economic Botanist.

I. INTRODUCTION.

THE methods of pollination and the possible occurrence of natural cross-fertilization in crops raised from seed are matters of the first importance both in the improvement, introduction and testing of varieties and also in the growth and distribution of seed to cultivators in India. In the present paper it is proposed to place on record some of the more important observations on these questions which have been made during the past four years in the Botanical area at Púsa, and also to discuss the bearing of the facts observed on the methods of improving the crops of India.

The Indian crops, which are raised from seed, fall, for the purposes of this paper, into three great divisions :—

A. Crops with closed flowers, such as the cereals and pulses. In this group self-pollination is likely to be the rule.

B. Crops with hermaphrodite open flowers, such as tobacco, *patwa* (*Hibiscus cannabinus*, L.), linseed, the *Brassica* oil seeds,

til (*Sesamum indicum*, L.), safflower (*Carthamus tinctorius*, L.), niger (*Guizotia abyssinica*, L.), cotton and opium poppy. In this group both self and cross-fertilization are likely.

C. Monœcious and diœcious crops or those in which the male and female flowers are separated; for example, maize, castor oil, *ganja* (*Cannabis indica*, L.) and the various cultivated *Cucurbitaceæ*. In such crops cross-fertilization on a large scale is to be expected.

It is principally with crops belonging to classes A and B that this paper deals.

The evidence on which we have based our opinion as to the occurrence of natural crossing in the crops of India has been entirely obtained from a study of single plant cultures. This is, in our judgment, the most reliable method known at present of obtaining accurate information on the subject. But little work on these lines seems to have been carried out previously due no doubt to the methods of mass selection till recently in vogue and to the time and space involved in the growth of the pure line cultures.

II. CROPS WITH CLOSED FLOWERS.

1. Wheat.

In general, the flowers of all the species and varieties of wheat are self-fertilized, pollination taking place before the extrusion of the anthers. Instances of undoubted natural crossing are rare in regions such as Northern Europe,[1] and some observers even state that it does not take place.[2] Three undoubted cases have been recorded in England and these have been referred to in a recent paper.[3]

While natural crossing seems to be exceedingly rare in damp climates, such as that of England, there is considerable evidence that it is more frequent in drier and more sunny climates like those of the continent of Europe and of North America. Cases of spontaneous crossing have been recorded by Le Couteur[4] in Jersey and by Koernicke[5] at Popplesdorf, while Fruwirth,[6] in a recent work, has brought together most of the recorded examples in the case of the wheat crop. Kiessling,[7] in Bavaria, has recently described eight cases of natural crossing among German wheats, and he considers that its occurrence is more frequent than is generally believed.

In a recent paper[3] we have discussed the occurrence of this phenomenon in India. Four cases of natural crossing were observed in the single ear cultures sown at Lyallpur in 1906, while a

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1 See Darwin, *Animals and Plants under Domestication*, and Biffen, *Journal of Agricultural Science*, Vol. I, 1905, p. 9.

2 See Garton, *Journal of the Farmers' Club*, 1900, p. 47, and De Vries, *Species and Varieties, their origin by Mutation*, 1906, p. 98.

3 Howard & Howard, *Memoirs of the Department of Agriculture in India* (*Botanical Series*), Vol. II, No. 7, 1909.

4 Le Couteur, *The Varieties, Properties and Classification of Wheat*, Jersey, 1872, p. 132.

5 Koernicke, *Die Arten und Varietäten des Getreides*, 1885, s. 31.

6 Fruwirth, *Die Zuchtung der landwirtschaftlichen Kulturpflanzen*, Bd. IV, 1907, s. 91.

7 Kiessling, *Fuhling's landwirtschaftliche Zeitung*, Bd. 57, 1908, s. 737.

further case was proved in 1908 in one of the plots of dwarf wheats at that station. It was further stated that in a large number of the plots at Lyallpur in 1908 (each grown from the produce of single ears sown in 1906), many stray plants were found, often more than one in a plot. These we considered were in all probability natural crosses in the F_1 generation. They have since been grown singly and their offspring examined.[1]

The results, arranged under the botanical variety in which the stray plants were found during the harvest of 1908, are given in the following tables:—

TRITICUM DICOCCUM, SCHRK. VAR. FARRUM, BAYLE.

In one of the plots of white chaff emmer belonging to the above variety three stray ears were found with red chaff. These in 1909 gave rise to the following:—

No.	Parent ear, 1908.	Progeny, 1909.
1	Bearded, chaff smooth red, grain red.	All (5) bearded, chaff smooth, grain red. 1 chaff white, rachis brittle. 2 ,, ,, rachis tough, grain easily shed. 2 chaff red, rachis brittle.
2	Do. do.	All (6) bearded, chaff smooth, grain red. 2 chaff white, rachis brittle. 4 ,, red ,, ,,
3	Do. do.	All (2) bearded, chaff smooth, grain red. 2 chaff red, rachis brittle.

As no red chaff emmer has yet been found in India, it is evident that the ordinary white chaff emmer has been crossed with a red chaff wheat, and probably one with a red grain. These are the only cases of natural crossing in emmer we have observed at Lyallpur. No cases have so far been observed at Púsa, where this variety has been grown for five years.

[1] These cultures were made in the Botanical area at the Cawnpore Experiment Station, as the conditions there are more favourable than at Púsa for the growth of Punjab wheats. We are indebted to Mr. H. M. Leake for facilities extended to us for this work and for the care of the cultures in the *rabi* season of 1908-09.

TRITICUM COMPACTUM, HOST. VAR. ERINACEUM, KCKE.

This bearded variety has smooth red chaff with short bristly spreading awns and small rounded red grains. Twenty-four stray ears were found in 1908 in the plots of this variety and these ears split up in 1909 as follows :—

No.	Parent ear, 1908.	Progeny, 1909.
4	Common wheat, bearded, chaff smooth red, grain red.	All (4) bearded, chaff smooth red, grain red. 2 dwarf wheats. 2 common wheats (one with somewhat rounded grains).
5	Common wheat, slightly bearded, chaff smooth red.	All (6) bearded, chaff smooth red, grain light red. 1 dwarf wheat, grain rounded. 5 common wheats, grain long.
6	Do. do.	All (5) bearded, chaff smooth red, grain red. 1 dwarf wheat. 4 common wheats.
7	Do. do.	All (16) chaff smooth red. 1 dwarf, beardless, very dense, grain red and rounded. 1 dwarf, short bristly awns, grain red and rounded. 3 common wheats, beardless, lax, grain red. 3 common wheats, beardless, lax, grain white. 3 common wheats, very slightly bearded, grain red. 1 common wheat, very slightly bearded, grain white. 1 common wheat, slightly bearded, grain red. 3 common wheats, fully bearded, grain red.
8	Do. do.	All (8) with smooth chaff. 1 dwarf wheat, beardless, chaff white, grain white. 1 dwarf wheat, beardless, chaff red, grain red. 1 intermediate between a dwarf and common wheat, bearded, glumes white and rounded, grain red. 1 common wheat, beardless, lax, chaff red, grain white. 4 common wheats, slightly bearded, chaff red, grain red.
9	Dwarf wheat, bearded, chaff felted red, grain red.	All (2) common wheats, bearded, chaff felted, grain red. 1 chaff densely felted red. 1 chaff felted white.
10	Do. do.	All (7) bearded, chaff felted, grain red. 1 dwarf wheat. 4 common wheats, chaff red. 2 common wheats, chaff white.
11	Do. do.	All (5) common wheats, bearded with red grain. 2 chaff felted red. 2 ,, ,, white. 1 chaff smooth red.
12	Do. do.	All (2) bearded, chaff densely felted. 1 dwarf wheat. 1 common wheat, chaff red, grain red.
13	Do. do.	All (4) common wheats, chaff densely felted red, grain red. 2 ears lax. 2 ears dense.

No.	Parent ear, 1908.	Progeny, 1909.
14	Dwarf wheat, bearded, chaff felted red, grain red.	All (4) bearded, chaff felted, grain red. 2 dwarf wheats, chaff slightly felted red. 1 common wheat, chaff densely felted white. 1 common wheat, lax, chaff red.
15	Do. do.	All (9) bearded, chaff felted, grain red. 1 dwarf wheat, chaff felted red, grain very rounded. 1 intermediate between a dwarf and common wheat, chaff densely felted red, grain rounded. 1 common wheat, chaff densely felted red, grain rounded. 1 common wheat, chaff red, grain not rounded. 1 common wheat, chaff sparsely felted, grain large and much rounded. 4 common wheats, chaff white, grain rounded.
16	Do. do.	All (2) bearded, chaff felted white, grain red. 1 dwarf wheat, grain rounded. 1 common wheat, grain long.
17	Do. do.	All (9) bearded, chaff felted, grain red. 2 dwarf wheats, chaff reddish, grain rounded. 1 common wheat, very dense, chaff densely felted reddish, grain rounded. 1 common wheat, similar to the above, but with lightly felted chaff. 3 common wheats, dense, chaff densely felted red. 1 common wheat, similar to the above, but grain very rounded. 1 common wheat, medium, chaff white, grain long.
18	Do. do.	All (3) bearded, chaff red, grain red. 1 dwarf wheat, chaff smooth. 1 common wheat, chaff smooth, grain rounded. 1 common wheat, chaff very densely felted.
19	Do. do.	Four plants obtained. 1 dwarf, bearded, chaff smooth white, grain red. 1 common wheat, beardless, chaff smooth red, grain white and rounded. 1 common wheat, bearded, chaff lightly felted red, grain red. 1 common wheat, bearded, chaff densely felted red, grain red and rounded.
20	Do. do.	All (8) bearded, chaff densely felted red, grain red. 1 dwarf wheat. 1 intermediate between a dwarf and a common wheat. 1 common wheat, dense, grain rounded. 5 common wheats, grain long.
21	Do. do.	All (17) bearded, chaff felted. 1 dwarf wheat, chaff lightly felted white, grain white and rounded. 2 dwarf wheats, chaff densely felted white, grain red and rounded. 4 dwarf wheats, chaff densely felted red, grain red and rounded. 7 common wheats, chaff densely felted red, grain red. 2 common wheats, chaff lightly felted red, grain red. 1 common wheat, chaff felted white, grain red.

No.	Parent ear, 1908.	Progeny, 1909.
22	Dwarf wheat, bearded, chaff felted red, grain red.	All (7) bearded, chaff felted, grain red. 2 dwarf wheats, slightly bearded, chaff red. 1 dwarf wheat, slightly bearded, chaff white. 2 common wheats, chaff red. 2 ,, ,, chaff white.
23	Do. do.	All (9) bearded, grain red. 2 dwarf wheats, chaff felted red. 2 common wheats, chaff lightly felted white. 3 ,, wheats, chaff felted white. 1 ,, ,, chaff densely felted red. 1 ,, ,, chaff smooth red.
24	Do. do.	All (15) bearded, chaff felted, grain red. 1 dwarf wheat, chaff densely felted white. 1 ,, ,, chaff ,, ,, red. 1 ,, ,, chaff lightly ,, white. 1 ,, ,, ,, ,, ,, red. 1 ,, ,, chaff felted red. 3 common wheats, chaff felted white. 2 ,, ,, chaff lightly felted red. 5 ,, ,, chaff densely felted red.
25	Do. do.	All (5) bearded, grain red. 1 dwarf wheat, chaff smooth red. 2 common wheats, chaff felted red. 2 ,, ,, ,, ,, white.
26	Do. do.	All (12) bearded, grain red. 1 dwarf wheat, chaff densely felted red. 1 ,, ,, ,, lightly felted white. 1 ,, ,, ,, smooth white. 1 intermediate between a dwarf and common wheat, chaff felted red, grain rounded. 4 common wheats, chaff densely felted red. 4 ,, ,, ,, lightly ,, red.
27	Do. do.	All (8) bearded, chaff felted, grain red. 2 dwarf wheats, chaff red. 1 common wheat, dense, chaff densely felted white. 1 ,, ,, dense, chaff white. 1 ,, ,, ,, chaff lightly felted red. 3 ,, wheats, medium, chaff felted red.

Triticum compactum, Host. var. linaza, Kcke.

In one of the plots of beardless felted white chaff dwarf wheat with a white grain belonging to this variety one stray plant was found in 1908, which in 1909 split up as follows :—

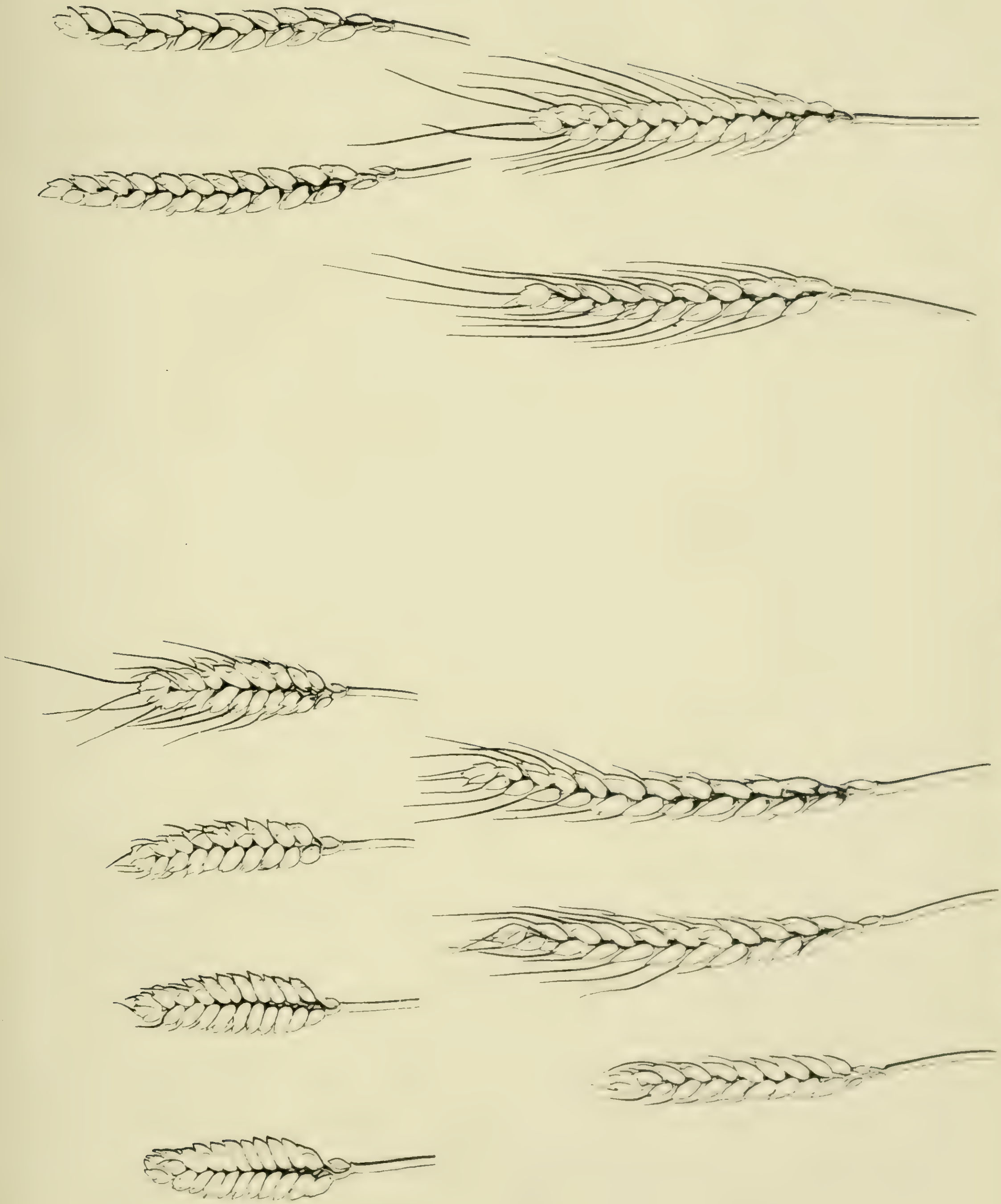
No.	Parent ear, 1908.	Progeny, 1909.
28	Common wheat, beardless, chaff felted red, grain white.	All (4) beardless, chaff lightly felted, grain white. 1 dwarf wheat, chaff red. 2 common wheats, chaff red. 1 ,, ,, ,, white.

Triticum compactum, Host. var. Humboldti, Kcke.

In this dwarf variety the ears are beardless with smooth white chaff and amber-coloured grain. Eight stray plants were found in 1908, which gave rise to the following progeny in 1909 :—

No.	Parent ear, 1908.	Progeny, 1909.
29	Dwarf wheat, slightly bearded, chaff smooth red, grain white.	All (23) chaff smooth white, grain white. (Plate 1.) 1 dwarf wheat, bearded. 6 dwarf wheats, slightly bearded. 1 dwarf wheat, beardless. 5 intermediate wheats, bearded. 2 ,, ,, slightly bearded. 2 ,, ,, beardless. 3 common wheats, bearded. 2 ,, ,, slightly bearded. 1 ,, wheat, beardless.
30	Do. do.	All (2) chaff smooth, grain white. 1 dwarf wheat, beardless, chaff red. 1 common wheat, slightly bearded, chaff white.
31	Do. do.	All (5) chaff smooth red, grain white. 2 dwarf wheats, beardless. 1 ,, wheat, bearded. 1 common wheat, slightly bearded. 1 ,, ,, fully bearded.
32	Dwarf wheat, bearded, chaff felted white, grain red.	All (6) chaff felted white, grain red. 1 dwarf wheat, beardless. 3 common wheats, slightly bearded. 2 ,, ,, fully bearded.
33	Dwarf wheat, beardless, chaff felted red, grain white.	All (13) beardless, grain white. 1 dwarf wheat, chaff smooth white. 2 ,, ,, chaff felted red. 2 common wheats, chaff felted white 2 ,, ,, chaff smooth red. 6 ,, ,, chaff felted red.
34	Dwarf wheat, very slightly bearded, chaff felted white, grain red.	All (11) chaff white, grain red. 1 dwarf wheat, beardless, chaff densely felted. 1 intermediate wheat, glumes smooth and rounded. 2 common wheats, beardless, chaff densely felted. 3 ,, ,, slightly bearded, chaff felted. 4 ,, ,, fully bearded, chaff densely felted.
35	Common wheat, beardless, chaff smooth white, grain white.	All (10) beardless, chaff smooth white, grain white. 1 dwarf wheat, grain rounded. 7 common wheats, grain long. 2 ,, ,, grain rounded.
36	Do. do.	All (3) beardless, chaff smooth white, grain white. 1 dwarf wheat. 1 common wheat, medium. 1 ,, ,, very lax.

PLATE I.



THE PROGENY OF A SLIGHTLY BEARDED DWARF WHEAT (No. 29).

TRITICUM VULGARE, VILL. VAR. ERYTHROSPERMUM, KCKE.

In the plots of this variety, the ears of which are bearded with smooth white chaff and red grain, a large number of stray plants were found in 1908. Their behaviour after sowing is given below :—

No.	Parent ear, 1908.	Progeny, 1909.
37	Bearded, awns black, chaff reddish, grain red.	All (4) bearded, chaff felted, grain red. 1 chaff reddish, grain like that of a macaroni wheat. 2 chaff densely felted white. 1 very late plant, chaff slightly felted reddish.
38	Bearded, chaff felted white, grain red.	All (2) bearded, chaff felted white, grain red. 1 chaff very densely felted. 1 ,, felted.
39	Beardless, chaff smooth red, grain white.	All (7) chaff smooth red, white grain. The seven plants differ in the degree of bearding.
40 to 76	Bearded, awns blackish, chaff white variously felted, grain red.	The progeny of these 36 plants varied in the degree of felting, in the density of the ear or in both of these respects. In crosses made between Punjab type 9 (felted wheat), and smooth chaff common wheats we have found in the F_2 generation a great preponderance of felted ears (100 felted to 7 smooth). There is every possible gradation between the densely felted and smooth ears in the F_2 generation, and the above examples of natural crossing bear a strong resemblance to the F_2 generation of our artificial crosses referred to. We have no doubt that all the 36 are true cases of natural crossing.
77	Beardless, chaff smooth red, grain red.	All (14) smooth chaff. 2 beardless, chaff white, grain red. 10 ,, ,, reddish, ,, ,, 1 ,, ,, ,, ,, white. 1 slightly bearded, chaff red, grain red.
78	Slightly bearded, chaff smooth red, grain red.	All (7) chaff smooth, grain red. 1 beardless, chaff white. 1 ,, ,, red. 1 half bearded, chaff white. 3 ,, ,, ,, red. 1 bearded, chaff red.
79	Do. do.	All (8) chaff smooth. 1 slightly bearded, chaff red, grain red. 6 half bearded, chaff red, grain red. 1 bearded, chaff white, grain white.
80	Bearded, awns black, chaff felted white, grain red.	All (14) bearded, chaff white, grain red. 9 chaff densely felted. 5 ,, lightly felted.
81	Do. do.	All (3) bearded, chaff white, grain red. 2 chaff felted. 1 ,, smooth.
82 to 85	Bearded, chaff felted white, grain red.	In these cases the progeny varied in the degree of felting only.

No.	Parent ear, 1908.	Progeny, 1909.
86	Bearded, chaff felted white, grain red.	All (6) bearded, chaff white, grain red. 1 chaff smooth. 1 ,, lightly felted. 1 ,, moderately felted. 3 ,, densely felted.
87	Do. do.	All (11) bearded, chaff white, grain red. 2 chaff smooth. 6 ,, lightly felted. 3 ,, moderately felted.
88	Do. do.	All (5) bearded, chaff white, grain red. 2 lax, chaff densely felted. 2 chaff moderately felted. 1 ,, lightly felted.
89	Do. do.	All (6) bearded, chaff white, grain red. 2 medium, densely felted. 1 lax, felted. 1 medium, lightly felted. 2 lax, smooth.
90	Do. do.	All (7) bearded, lax, chaff white, grain red. 1 chaff smooth. 4 ,, lightly felted. 1 ,, moderately felted. 1 ,, densely felted.
91	Do. do.	All (9) bearded, lax, chaff white, grain red. 7 chaff densely felted. 1 ,, moderately felted. 1 ,, smooth.
92	Do. do.	All (9) bearded, chaff white, grain red. 1 chaff smooth. 3 ,, lightly felted. 5 ,, densely felted.
93	Do. do.	All (11) bearded, chaff white, grain red. 2 chaff smooth. 4 ,, lightly felted. 5 ,, felted.
94	Do. do.	All (11) bearded, chaff white, grain red. 2 chaff smooth. 4 ,, lightly felted. 5 ,, felted.
95	Do. do.	All (10) bearded, chaff white, grain red. 1 chaff smooth. 2 ,, very lightly felted 2 ,, lightly felted. 2 ,, moderately felted 3 ,, densely felted
96	Do. do.	All (7) bearded, chaff white, grain red. 1 chaff smooth. 2 ,, lightly felted. 4 ,, felted.
98 and 99	Do. do.	All bearded, chaff felted white, grain red. In these two cases the plants varied in the degree of felting only.

No.	Parent ear, 1908.	Progeny, 1909.
100	Bearded, chaff felted white, grain red.	All (4) bearded, chaff white, grain red. 1 dense, chaff densely felted. 3 lax, chaff slightly felted.
101	Bearded, lax, chaff felted white, grain red.	All (6) chaff white, grain red. 1 beardless, medium, chaff very densely felted 1 beardless, lax, chaff moderately felted. 1 slightly bearded, medium, chaff very densely felted. 1 slightly bearded, medium, chaff moderately felted. 2 bearded, chaff densely felted.
102	Do. do.	All (7) bearded, lax, grain red. 1 chaff almost smooth. 3 ,, lightly felted. 3 ,, moderately felted.
103	Do. do.	All (6) bearded, lax, chaff white, grain red. 1 chaff smooth. 3 ,, lightly felted. 2 ,, moderately felted.
104	Do. do.	All (11) bearded, lax, chaff white, grain red. 4 chaff smooth. 7 ,, lightly felted.
105	Do. do.	All (2) bearded, lax, chaff white, grain red. 1 chaff densely felted. 1 ,, lightly felted.
106	Do. do.	All (5) bearded, lax, chaff white, grain red. 1 chaff felted. 4 ,, lightly felted.
107 to 111	Do. do.	In these five cases the progeny differed in the degree of felting only.
112	Do. do.	All (5) bearded, chaff white, grain amber-coloured. 3 black awns, chaff densely felted. 1 white ,, ,, moderately felted. 1 ,, ,, ,, very slightly felted.
113	Do. do.	All (5) bearded, chaff slightly felted white, grain red. 3 medium. 2 lax.
114	Do. do.	All (4) bearded, chaff white, grain red. 1 lax, chaff densely felted. 1 ,, ,, lightly felted. 1 ,, ,, smooth. 1 dense, chaff densely felted, grain short.
115 to 118	Bearded, chaff smooth red, grain red.	In these four cases the progeny was bearded, with smooth chaff and red grain. Red chaff and white chaff plants however occurred in each case.
119	Do. do.	All (7) bearded, chaff smooth. 2 chaff red, grain red. 2 ,, ,, grain white. 2 ,, white, grain white. 1 ,, ,, ,, red.

No.	Parent ear, 1908.	Progeny, 1909.
120	Bearded, chaff smooth red, grain red.	All (3) bearded, chaff smooth *white* and grain red. In this case a red chaff parent has given white chaff offspring.
121	Slightly bearded, chaff smooth white, grain red.	All (2) chaff smooth white. 1 beardless, grain red. 1 slightly bearded, grain white.
122	Do. do.	All (5) chaff smooth white. 1 beardless, lax, grain white. 1 slightly bearded, lax, grain red. 1 ,, ,, ,, ,, white. 1 ,, ,, medium, grain white. 1 bearded, lax, grain white.
123	Slightly bearded, chaff felted red, grain red.	All (6) chaff smooth red, grain red. 1 fully bearded. 1 half bearded. 1 very slightly bearded. 3 beardless.
124	Ears square, bearded with black awns, chaff felted white, grain red.	All (2) bearded, chaff densely felted white, grain red. 1 lax. 1 dense.
125	Do. do.	All (7) bearded, lax, chaff white, grain red. 5 chaff densely felted, awns black. 1 ,, slightly felted, awns white. 1 ,, smooth, awns white.
126	Do. do.	All (17) bearded, chaff white, grain red. 8 chaff densely felted. 4 ,, moderately felted. 3 ,, slightly felted. 2 ,, smooth.
127	Do. do.	All (8) bearded, chaff white, grain red. 4 chaff densely felted, awns black. 3 ,, moderately felted, awns black. 1 ,, slightly felted, awns white.
128	Do. do.	All (16) bearded, white chaff, grain red. 5 chaff densely felted. 2 ,, less densely felted. 7 ,, slightly felted. 2 ,, smooth.
129	Do. do.	All (19) bearded, chaff white, grain red. 2 chaff smooth. 4 ,, slightly felted. 5 ,, moderately felted. 8 ,, densely felted.
130	Do. do.	All (12) bearded, chaff white, grain red. 10 chaff felted (density of ear and degree of felting varies). 2 chaff smooth.
131 and 132	Do. do.	All bearded, chaff felted white, grain red. In these two cases the plants differed in density and in the degree of felting.

No.	Parent ear, 1908.	Progeny, 1909.
133 to 136	Bearded, chaff felted white, grain red.	All (5) bearded, chaff white, grain red. In all cases the plants differed in the degree of felting only.
137	Do. do.	All (8) bearded, chaff white, grain red. 3 chaff densely felted. 4 ,, moderately felted. 1 ,, smooth.
138	Do do.	All (10) bearded, chaff white, grain red. 5 chaff densely felted. 4 ,, slightly felted 1 ,, smooth.
139	Do. do.	All (12) bearded, chaff white, grain red. 8 chaff densely felted. 3 ,, slightly felted. 1 ,, smooth.

TRITICUM VULGARE, VILL. VAR. ERYTHROLEUCON, KCKE.

In this bearded variety with felted red chaff and white grain, twelve cases of natural crossing were discovered in 1908. The progeny of these stray plants in 1909 is described below :—

No.	Parent ear, 1908.	Progeny, 1909.
140	Plant like a macaroni wheat with felted reddish chaff and white grain.	All (4) bearded, awns black, chaff red, outer glumes sharply keeled to the base. 1 dense, rounded felted glumes, no grain. 1 lax, chaff smooth, no grain. 1 ,, chaff felted, grain white. 1 ,, black awns, straw solid, chaff felted.
141	Bearded, chaff felted reddish, grain red.	All (8) bearded, grain red. 4 chaff felted red. 2 ,, ,, white 2 ,, smooth red.
142 to 146	Beardless, chaff smooth red, grain white.	In all five cases the chaff was smooth and the grain white. In all instances red and white chaff and beardless and variously bearded plants occurred.
147	Slightly bearded, chaff smooth red, grain white.	All (6) chaff smooth red, grain white. 1 beardless. 1 slightly bearded. 3 half bearded. 1 fully bearded.
148	Do. do.	All (8) chaff smooth, grain white. 4 beardless, chaff red. 1 slightly bearded, chaff white. 3 half bearded, chaff red.
149	Bearded, chaff felted red, grain red.	All (10) bearded, chaff red. 1 chaff smooth, grain red. 7 ,, densely felted, grain red. 2 ,, ,, ,, ,, white.

No.	Parent ear, 1908.	Progeny, 1909.
150	Bearded, chaff felted red, grain red.	All (7) bearded, red grain. 1 chaff red smooth. 1 ,, red slightly felted. 2 ,, ,, densely ,, 2 ,, white slightly ,, 1 ,, ,, very densely felted.
151	Do. do.	All (12) bearded. 3 chaff densely felted white, grain red. 1 ,, moderately felted white, grain red. 4 ,, densely felted red, grain red. 3 ,, slightly felted red, grain red. 1 ,, smooth red, grain white.

Triticum vulgare, Vill. var. graecum, Kcke.

In the plots of this bearded variety with smooth white chaff and white grain a large number of aberrant plants were found in 1908 which split up in 1909 as follows :—

No.	Parent ear, 1908.	Progeny, 1909.
152	Beardless, chaff smooth white, grain white.	All (7) chaff smooth white, grain white. 5 beardless. 1 half bearded. 1 fully ,,
153	Slightly bearded, chaff red slightly felted, grain red.	All (5) chaff slightly felted, grain white. 1 bearded, chaff white. 1 beardless, ,, ,, 3 slightly bearded, chaff red.
154	Do. do.	All (3) slightly bearded, lax, grain white. 1 chaff red felted. 1 ,, white smooth. 1 ,, felted white.
155	Bearded, chaff smooth red, grain white.	All (9) bearded, chaff smooth grain white. 6 chaff red. 3 ,, white.
156 and 157	Bearded, chaff felted white, grain red.	All bearded, chaff felted white, grain red. In both cases the various plants differed in the degree of felting.
158	Do. do.	All (11) bearded, chaff white. 6 densely felted, grain red. 1 densely ,, ,, white. 4 slightly ,, ,, red.
159	Do. do.	All (6) bearded, chaff white, grain red. 1 chaff smooth. 2 ,, lightly felted. 3 ,, densely ,,
160	Do. do.	All (11) bearded, chaff white, grain red. 1 chaff smooth.

No.	Parent ear, 1908.	Progeny, 1909.
		2 chaff slightly felted. 6 ,, moderately felted. 2 ,, densely felted.
161	Bearded, chaff felted white, grain red.	All (7) bearded, chaff white. 1 chaff smooth, grain red. 1 ,, ,, ,, white. 3 moderately felted, grain red. 1 densely felted, grain red. 1 ,, ,, ,, white.
162	Bearded, awns black, chaff felted white, grain red.	All (11) bearded, chaff white, grain red. All the plants differed in the degree of felting and in the density of the ear.
163	Do. do.	All (16) bearded, chaff white. 2 chaff densely felted, grain red and rounded. 1 ,, densely felted, grain white. 6 ,, moderately felted, grain red. 1 ,, slightly felted, grain white. 3 ,, slightly felted, grain red. 1 ,, ,, ,, red and rounded. 2 ,, smooth, grain white.
164 to 166	Bearded, chaff felted white, grain red.	All bearded, chaff white. In each case the plants differed both in the degree of felting and in the colour (red or white) of the grain.
167	Do. do.	All (17) bearded, chaff white. 2 chaff smooth, grain white. 10 ,, felted, ,, red. 5 ,, ,, ,, white.
168	Do. do.	All (5) bearded, chaff white, grain red. 1 chaff smooth, grain rounded. 1 ,, slightly felted, grain rounded 2 ,, ,, ,, grain long. 1 ,, densely felted.
169	Do. do.	All (14) bearded, chaff white. 2 chaff densely felted, grain white. 1 ,, slightly felted, grain white. 5 ,, densely felted, grain red. 4 ,, moderately felted, grain red 1 ,, slightly felted, grain red. 1 ,, smooth, grain red.
170	Bearded, chaff slightly felted red, grain red.	All (15) bearded. 1 chaff red smooth, grain red. 7 ,, ,, felted ,, ,, 6 ,, white felted ,, ,, 1 ,, ,, ,, ,, white.
171	Do. do.	All (6) bearded, lax, chaff smooth red. 5 grain red. 1 ,, white.
172	Do. do.	All (9) bearded, lax. 2 chaff smooth red, grain red. 4 ,, very slightly felted red, grain red. 1 ,, slightly felted red, grain white. 1 ,, moderately felted red, grain red. 1 ,, moderately felted white, grain red.

No.	Parent ear, 1908.	Progeny, 1909.
173	Bearded, chaff slightly felted red, grain red.	All (10) bearded. 1 chaff smooth white, grain white. 2 ,, ,, ,, ,, red. 2 ,, smooth red, grain white. 3 ,, ,, ,, ,, red. 2 ,, slightly felted red, grain red.
174	Do. do.	All (10) bearded. 3 chaff smooth red, grain white. 1 ,, ,, ,, ,, red. 1 ,, slightly felted red, grain white. 5 ,, smooth white, grain red.
175	Do. do.	All (11) bearded, chaff very slightly felted red. 5 grain white. 6 ,, red.
176	Do. do.	All (8) bearded. 1 chaff slightly felted red, grain white. 1 ,, smooth, red. 5 ,, slightly felted red, grain red. 1 ,, slightly felted white, grain white.

Triticum vulgare, Vill. var. alborubrum, Kcke.

In one of the plots of this beardless variety with smooth red chaff and white grain one aberrant plant was found in 1908 which split, in 1909, as follows :—

No.	Parent ear, 1908	Progeny, 1909.
177	Bearded, chaff reddish smooth, grain white.	All (2) bearded with smooth white chaff and white grain.

Triticum vulgare, Vill. var. fuliginosum, Al.

In the plots of this variety (bearded, densely felted grey chaff and red grain) on the Lyallpur farm, a large number of aberrant plants were found in 1908 which, when sown separately, behaved as follows :—

No.	Parent ear, 1908.	Progeny, 1909.
178	A macaroni like wheat, bearded, chaff smooth reddish, grain white.	All (3) bearded, chaff smooth, grain white. 2 chaff red. 1 ,, white.
179	Bearded, lax, chaff felted white, grain red.	All (12) bearded, lax, chaff white, grain red. 8 chaff very densely felted. 4 ,, less ,, ,,

No.	Parent ear, 1908.	Progeny, 1909.
180	Bearded, chaff red felted, grain white.	All (24) bearded, grain white. 4 chaff densely felted white. 14 ,, less densely felted red. 6 ,, slightly felted red.
181	Do. do.	All (8) bearded, grain white. 1 chaff felted white. 3 ,, densely felted red. 3 ,, felted light-red. 1 ,, lightly felted red.
182	Do. do.	All (13) bearded, chaff felted, grain white. 5 chaff white. 8 ,, red.
183	Slightly bearded, chaff felted white, grain red.	All (4) chaff white felted, grain white. 2 bearded. 1 slightly bearded. 1 beardless.
184	Do. do.	All (4) chaff felted white. 1 bearded, grain red. 1 slightly bearded, grain red. 1 beardless, grain red. 1 ,, grain white.
185	Do. do.	All (8) chaff white, grain red. 2 bearded, chaff densely felted. 1 ,, chaff slightly ,, 3 slightly bearded, chaff densely felted. 2 beardless, chaff densely felted.
186	Do. do.	All (5) densely felted, chaff white, grain red. 1 beardless. 2 slightly bearded. 2 bearded.
187	Do. do.	All (13) densely felted, chaff white, grain red. 2 beardless. 8 slightly bearded. 3 fully ,,
188	Do. do.	All (2) chaff white, grain red. 1 slightly bearded, chaff densely felted. 1 fully bearded, chaff moderately
189	Do. do.	All (12) chaff white variously felted. 3 fully bearded, grain dark amber. 1 fully bearded, ,, clear white. 4 half bearded. 3 slightly ,, 1 beardless.
190	Do. do.	All (10) felted, chaff white. 1 fully bearded, grain white. 1 slightly bearded, ,, ,, 4 ,, ,, ,, red. 3 beardless, grain red. 1 ,, ,, white.
191	Do. do.	All (5) chaff variously felted white, grain red. 1 dwarf wheat, bearded, grain rounded.

No.	Parent ear, 1908.	Progeny, 1909.
		1 dwarf wheat, rather lax, beardless, grain long. 1 intermediate wheat, grain rounded. 1 ,, ,, ,, long. 1 common beardless wheat, grain long.
192	Slightly bearded, chaff felted white, grain red.	All (14) chaff variously felted white, grain red. 2 bearded. 6 slightly bearded. 6 beardless.
193	Do. do.	All (9) chaff felted white. 2 bearded, grain red. 1 ,, ,, white. 4 slightly bearded, grain red. 2 beardless, grain red.
194	Beardless, chaff felted white, grain red.	All (14) beardless, chaff white, grain red. 6 chaff smooth. 4 ,, felted 4 ,, slightly felted.
195 to 198	Do. do.	All beardless, chaff white, grain red. The plants in each culture differed in the degree of felting only.
199	Do. do.	All (3) beardless, chaff densely felted white, grain red. 2 dense ears. 1 very lax ear.
200	Slightly bearded, chaff felted red, grain red.	All (24) chaff densely felted, grain red. 2 bearded, dense, chaff red. 2 ,, chaff white. 13 slightly bearded, chaff red. 7 beardless, chaff red.
201	Do. do.	All (20) chaff red, grain red. 2 bearded, chaff slightly felted. 7 slightly bearded, chaff variously felted. 3 slightly bearded, ,, smooth. 3 beardless, chaff felted. 5 ,, ,, smooth.
202	Do. do.	All (12) moderately felted, chaff reddish, grain red. 2 beardless. 5 slightly bearded. 5 bearded.
203	Do. do.	All (14) chaff red. 1 beardless, chaff densely felted, grain white. 2 beardless, ,, slightly felted, grain red. 4 beardless, ,, densely ,, ,, ,, 2 slightly bearded, chaff moderately felted, grain red. 3 slightly bearded, ,, slightly felted, ,, ,, 1 bearded, chaff slightly felted, grain red. 1 bearded, ,, moderately felted, grain red.
204	Do. do.	All (12) chaff variously felted. 1 slightly bearded, chaff white, grain red. 3 beardless, chaff white, grain red. 1 ,, ,, ,, grain white. 6 ,, ,, red, grain red. 1 ,, very dense, chaff red, grain red.

No.	Parent ear, 1908.	Progeny, 1909.
205	Slightly bearded, chaff felted red or reddish, grain red.	All (6) chaff felted, grain red. 2 beardless, chaff white. 2 ,, ,, red. 1 slightly bearded, chaff red. 1 half ,, ,,
206	Do. do.	All (10) chaff felted. 3 slightly bearded, chaff red, grain red. 2 ,, ,, ,, ,, ,, white. 1 ,, ,, ,, white, grain red. 2 bearded, chaff red, grain red. 2 ,, ,, white, grain ,,
207	Do. do.	All (22) chaff felted. 1 bearded, chaff red, grain white. 1 ,, ,, ,, ,, red. 1 ,, ,, white, ,, ,, 9 slightly bearded, chaff red, grain red. 4 slightly bearded, chaff white, grain red. 4 beardless, chaff red, grain red. 2 ,, chaff white, ,, ,,
208	Do. do.	All (6) chaff felted, grain red. 1 beardless, chaff white. 1 ,, ,, red. 3 slightly bearded, chaff red. 1 ,, ,, ,, white.
209	Do. do.	All (18) chaff felted. 1 beardless, dense, chaff red, grain red and rounded. 1 ,, medium, chaff red, grain red and long. 1 ,, lax, chaff red, grain ,, ,, 1 slightly bearded, chaff red, grain white. 10 ,, ,, ,, ,, ,, ,, 1 ,, ,, chaff white, grain red. 1 bearded ,, ,, ,, ,, 2 ,, chaff red, grain red.
210	Do. do.	All (11) chaff white. 3 half bearded, chaff densely felted, grain red. 1 half bearded, chaff slightly ,, ,, ,, 1 slightly bearded, chaff slightly felted, grain white. 4 beardless, chaff densely felted, grain red. 1 ,, ,, ,, ,, ,, ,, 1 ,, ,, smooth, grain red.
211	Do. do.	All (10) chaff felted, grain red. 6 slightly bearded. 4 beardless.
212	Do. do.	All (4) chaff felted, grain red. 1 beardless, dense, chaff red. 1 slightly bearded, lax, chaff white. 1 ,, ,, ,, ,, red. 1 bearded, very lax, grain like that of a durum wheat.
213	Do. do.	All (3) chaff densely felted, grain red. 1 beardless, chaff white. 1 half bearded, chaff red. 1 bearded, chaff white.

No.	Parent ear, 1908.	Progeny, 1909.
214	Slightly bearded, chaff felted red or reddish, grain red.	All (7) chaff variously felted white. 1 beardless, grain white. 3 ,, ,, red. 2 slightly bearded, grain red. 1 half bearded ,, ,,
215	Do. do.	All (11) chaff variously felted, grain red 1 beardless, chaff red. 1 slightly bearded, chaff white. 5 ,, ,, ,, red. 4 fully bearded, chaff red.
216	Do. do.	All (5) chaff variously felted, grain red. 1 half bearded, chaff white. 2 ,, ,, ,, red. 2 fully bearded, chaff red.
217 to 221	Beardless, chaff felted, grain red.	In these five cases all the plants were beardless, with red felted chaff and red grain. They differed in the density of the ear and in the degree of felting.
222	Do. do.	All (9) chaff felted, grain red. 2 slightly bearded, chaff red. 2 ,, ,, ,, white. 4 beardless, chaff red. 1 ,, ,, white.
223	Do. do.	All (4) chaff variously felted. 2 beardless, chaff red, grain red. 1 slightly bearded, chaff white, grain white. 1 bearded, chaff white, grain red.
224	Do. do.	All (4) chaff variously felted, grain red. 1 slightly bearded, chaff white. 3 beardless, chaff reddish.
225	Do. do.	All (2) beardless, dense, chaff red, grain red. 1 chaff smooth. 1 ,, slightly felted.
226	Do. do.	All (12) grain red. 2 beardless, chaff felted red 1 slightly bearded, chaff slightly felted white. 1 ,, ,, densely ,, ,, 3 ,, moderately felted red. 1 beardless, chaff red smooth. 4 ,, ,, slightly felted.

Five cases of natural crossing in wheat in Bihár have been proved. In 1908, 130 single ear cultures of the wheats of Bengal were sown in the Botanical area at Púsa. Four of these proved to be natural crosses. One of the ears was obtained from a culture which had been grown for a year at Púsa, the other three were grown from ears found in the cultivators' fields in North Bihár. The fifth case of natural crossing occurred at Púsa

in a plot of wheat which had been grown from one plant selected in 1906.

The three cases of natural crossing in cultivators' fields in North Bihár were as follows: In the first case, a bearded smooth red chaff ear, sown in 1908, split up into red and white chaff plants in 1909. In the second case, one ear of a black awned common wheat with blackish chaff, sown in 1908, gave rise in 1909 to two kinds of plants—plants with black chaff on a red ground and plants with black chaff on a white ground. One of each of these two classes of plants were sown in 1909 and during the present year (1910) both have split still further. The plant with black chaff on a white ground gave white chaff plants as well as plants like the parent ear. The plant with black chaff on a red ground gave four classes of plants, white chaff, red chaff, black chaff on a white ground, and black chaff on a red ground. The third case was observed in a bearded smooth chaff ear sown in 1908 which gave rise to apparently uneven progeny in 1909. It was not possible to determine with certainty the characters of the chaff of the progeny of this culture in 1909 as the plants ripened late and were not fully developed. Eight single plants were selected and sown separately in October 1909. Six of these came uniform like the original parent and two split, one into red and white chaff and the other into red, white, black on white and black on red chaff.

The two cases of natural crossing which have been proved in the Botanical area at Púsa are the following. A slightly bearded white chaff plant was observed in 1909 in one of the plots raised from a single ear in 1906. This when sown separately gave slightly bearded, beardless and fully bearded ears in 1910. The second case was observed in one of the single ear cultures of Bengal wheats in 1909 when a white chaff bearded ear gave bearded white chaff plants, and one black chaff plant in 1909. This latter sown separately in the same year gave, in 1910, both white and black chaff plants.

In addition to the five cases of natural crossing at Púsa described above, a number of stray plants were found both in 1909 and again in 1910 in some of the larger plots originally grown from one plant in 1906. As these strays differed from any wheats grown at Púsa we are inclined to believe they were natural crosses. Time and space did not permit us to grow them on and prove their origin and they were accordingly thrown away. Natural crossing in wheat undoubtedly takes place at Púsa to a small extent, but its occurrence bears no comparison to the frequency of this phenomenon at Lyallpur.

It will be evident from the above that natural crossing in wheat is far more frequent under the conditions obtaining on the Canal Colonies of the Punjab than it is in Bihár. At Púsa five cases have been proved. Two hundred and thirty-one cases were proved by us at Lyallpur, and of these no less than two hundred and twenty-six took place in 1907. In the dry climate of the Chenab Colony wheat is grown entirely by Canal irrigation and is usually watered at least twice after sowing, the last watering taking place after the plants are in ear. Often before this last irrigation the supply of water in the soil is so small that the plants wilt during the hottest part of the day, the glumes open and the stigmas are exposed to the air. Under such circumstances, in the dry hot climate, natural crossing is easy and it is not surprising therefore that it is so frequent. Experimental cultures might be protected to some extent from natural crossing by more frequent and even watering. Wheat-breeding will always be very difficult at Lyallpur, and it will be necessary to bag the F_1 generation at least. Pure line cultures will have to be rogued every year and frequently re-selected, and the trouble and difficulty of growing pure seed for cultivators will be considerable.

In the damper climate of North Bihár where wheat is grown without irrigation on high moisture retaining loams natural crossing although occurring gives little trouble in selection and breeding work.

It will be evident that the environment may modify to a considerable extent the usual pollination mechanism in a crop. In Northern Europe cross-pollination in wheat is a rare occurrence, in warmer climates it is more frequent while in hot dry localities such as the Canal Colonies of the Punjab where the crop can only be grown by means of artificial irrigation, cross-pollination is quite common.

2. Barley.

A large number of pure line cultures of barley, belonging to different varieties, have been grown at Púsa, but no cases of natural crossing have so far been observed. Natural crossing, however, occurs sparingly in this crop as Rimpau[1] found six cases in eight years.

3. Peas.

In India, as in Europe, the cultivators recognise two great groups of cultivated peas—purple flowered peas (*Pisum arvense*, L., known in India as *kerao*) and white flowered peas (*Pisum sativum*, L., known as *mattar*).

It is generally understood in Europe that in both these groups self-pollination is the rule and that natural cross-fertilization does not take place.[2] Two cases of undoubted natural cross-fertilization have been proved at Púsa between Indian forms of the purple and white flowered groups.

In the case of *kerao*, 28 plants were selected from the harvest of 1909 and sown separately the following October. In 27 cases the progeny was uniform but in one instance splitting took place. Some plants had uniformly green leaves, others were reddish on the margin. Late and early and small and large seeded plants occurred. Seven plants had seeds with black spots only, two plants had seeds with black and brown spots. In this case crossing

[1] Rimpau, *Landwirtschaftliche Jahrbücher*, Bd. XX, 1891, s. 357.

[2] See *Fruwirth, Die Zuchtung*, Bd. III, 1908, s. 135; Lock, *Annals Royal Botanic Gardens, Peradeniya*, Vol. II, 1904-05; Rimpau, *Land. Jahrbücher*, 1891, s. 366 and Tschermak *Zeit. f. d. land. Versuchswesen in Oesterreich*, Bd. III, 1900, s. 473.

must have taken place between two related types of *Pisum arvense.*

In the case of *Pisum sativum* (*mattar*) 29 single plants were sown in 1909, and at the harvest of 1910 three of these gave rise to mixed offspring. The history of these splitting cases is as follows: In a plot of this crop raised from local seed in 1908 four greenish seeds with black spots were selected. Probably these were taken from a single plant, but on this point we are not certain. However, these four seeds were sown separately in October 1908 and gave rise to four plants as follows :—

Selected from 1908 crop.	Raised in 1908-09.	Raised in 1909-10 from the single plants of 1909.
Four large greenish seeds with black spots.	Flowers white, seed white.	Flowers white, seed white.
	Flowers purple, seed green without spots.	Flowers white, seed white (6). ,, purple, seed green without spots (16).
	Flowers purple, seed green with a few violet spots.	Flowers white, seed white (6). ,, purple: seed green with violet spots (9); seed green without spots (1).
	Flowers purple, seed green with many violet spots.	Flowers white, seed white (4). ,, purple, seed green with violet spots. (17).

Natural crossing has undoubtedly taken place between *mattar* and *kerao*, and as far as we can find, the above is the only case on record of a cross having taken place between purple and white flowered peas. (Plate II.)

4. KHESARI. (LATHYRUS SATIVUS, L.)

This vetch known as *khesari*[1] is widely cultivated in India for food. We have found no record of any work having been done in India on the pollination of this species. Kirchner[2] observed the honey-bee on cultivated plants in Wurtemburg. When it settled in the middle of the flower, it was dusted with pollen

[1] Watt, *The Commercial Products of India*, London, 1908, p. 703.

[2] Knuth, *Handbook of Flower Pollination*, Vol. II, 1908, p. 334.

THE PROGENY OF A PURPLE-FLOWERED PEA.

PLATE III.

NATURAL CROSSING IN KHESARI.

(The numbers refer to the Table opposite.)

on its right side behind the head, and it regularly effected cross-pollination.

It was observed at Púsa in plots raised from local seed that, while the great majority of the plants have blue flowers and breed true, nevertheless a few plants occurred with pink and sometimes reddish flowers.

Ten single plants obtained from a culture raised from pink flowered plants in 1908 were selected in the harvest of 1909 and sown the following October. In 1910 nine of these plants split up as follows :—

	Single plants sown in 1909.	Progeny in 1910.
1	Plant with blue flowers.	Flowers blue (22). Flowers pink (9).
2	Plant with pink flowers.	Flowers blue Flowers blue with a pink border (7). Flowers pink (12).
3	Do.	Flowers blue Flowers blue with a pink border (4). Flowers pink (28).
4	Plant with light pink flowers.	Flowers blue (2). Flowers light pink (20).
5	Do.	Flowers blue (3). Flowers light pink (23).
6	Plant with blue flowers.	Flowers blue with pink border ,, ,, without border (23). Flowers light pink (8). Flowers pink (1).
7	Plant with red flowers.	Flowers red (33). Flowers blue (1).
8	Plant with blue flowers.	Flowers red (6). Flowers blue (22).
9	Do.	Flowers red (5). Flowers blue (23).
10	Plant with red flowers.	Flowers all red. Progeny in all respects like the parent.

Thus nine out of ten single plant cultures split and proved to be natural crosses. Only one red flowered plant bred true. In addition to the differences in the colour of the flowers there were slight differences in the colour of the seeds of the progeny of the crossed plants.

5. Beans.

One case of natural crossing in beans (*Vicia faba*, L.) has been met with at Púsa. In 1909, eight single plants were sown, of which seven bred true and one split as regards the colour of the seeds. The eight cultures belonged to two varieties, one with green seeds the other with black seeds. The four lines with green seeds bred true, one line of the black seeded variety gave six plants with green seed and eight with black or blackish seeds. The other three black seeded lines bred true.

5. Other leguminous crops.

Lentil. The flowers of the lentil (*Lens esculenta*, Moench.) have not yet been studied in detail by us. Eight single plant cultures were made in 1908 and in all cases bred true.

Gram. Several distinct varieties of gram (*Cicer arietinum*, L.) occur mixed together in the crop as ordinarily grown in India. In 1909, 12 single plants were selected which bred true.

San. In *San* (*Crotalaria juncea*, L.) no cases of natural crossing have been observed yet between the two varieties of this crop described by us in a previous paper.[1]

[1] Howard and Howard, *Memoirs of the Department of Agriculture in India* (*Botanical Series*), Vol. III, No. 3, 1910.

III. CROPS WITH OPEN FLOWERS.

1. Tobacco.

Two species of tobacco are cultivated in India, namely, *Nicotiana tabacum*, L., and *N. rustica*, L. The cultivated Indian types of both of these species have been described by us in previous papers[1] and, in addition, the methods of pollination and the frequency of natural cross-fertilization have been studied.

In the flowers of *N. rustica* the anthers always burst in the bud before the corolla opens and the stigma is receptive at the same time. Homogamy is, therefore, the rule. The relative position of the stigma and anthers, however, was found to vary considerably between the various types. The general scheme was found to be as follows: the anthers just before the flowers open are either below, opposite or above the stigma, and in all cases bend towards it. When the pollen is shed, the style elongates and lifts the stigma a little. Then the corolla begins to fade and the anthers recede from the stigma. Every gradatfon was found in the various types between the condition in which the stamens were above the stigma throughout, rendering cross-pollination practically impossible, and the other extreme case in which all the stamens are so much shorter than the style that self-pollination is only possible by insects or by wind shaking the flowers. Many small bees were noticed visiting the flowers, and some small flies, covered with pollen, were observed inside the corolla tubes. The arrangements for pollination in the various types can be divided into the following three classes (Plate IV) :—

Class I. Stamens much longer than the style.

In this class the style is decidedly shorter than the stamens, so that the four longest stamens bend over the stigma, and in an

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[1] Howard and Howard, *Memoirs of the Department of Agriculture in India (Botanical Series)*, Vol. III, Nos. 1 & 2, 1910.

open flower the stigma is not visible, being always covered by the stamens. In such flowers cross-pollination is almost impossible.

Class II. Stamens about the same length as the style.

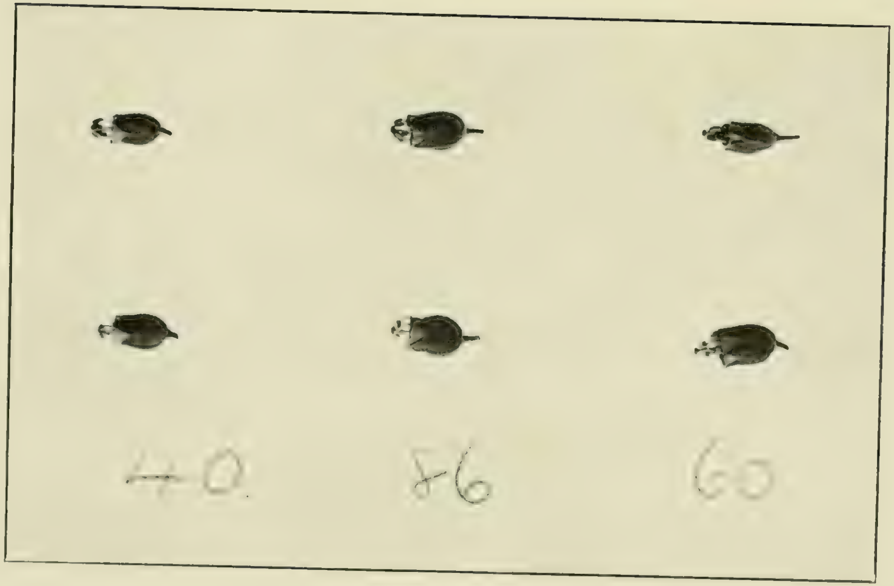
This class includes the various conditions intermediate between classes I and III, and comprises the majority of the types. The stamens may be a very little longer than the style, so that about half the anther projects above the stigma and the latter in the opened flower is surrounded by the burst anthers, but is not obscured by them as in class I. In other cases the tip of the anther only may project above the stigma and the pollen is deposited round its edge just before the corolla opens, while in the fully open flower the empty anthers are clustered round the style just below the stigma. In a few types the anthers may just touch the stigma and the pollen is deposited at its extreme edge or else beneath it. In such cases the anthers are sometimes rather late in bursting and very little pollen is shed before the flower opens.

It is clear that very small differences in the length of the stamens would produce any of these three conditions, and it is not surprising to find that a certain amount of difference can sometimes be found in the flowers of the same plant. For instance, in plants where the anthers normally just touch the stigma, it is usual to find some flowers in which they escape touching it. Thus, in some flowers cross-pollination would be more favoured, in others self-pollination.

Class III. Style much longer than the stamens.

This extreme condition in which the stigma grows out of the unopened bud into the air, and in which self-pollination is exceedingly difficult, was only met with in one case. In this type very few capsules naturally set seed, and it was only possible to obtain seed under bag by artificial selfing.

These observations point to the likelihood of the frequent occurrence, under Indian conditions, of natural cross-fertilization in the field when the types are grown next to next. That natural



SHORT, INTERMEDIATE AND LONG-STYLED FLOWERS
OF N. RUSTICA.

crossing actually does take place under these circumstances was proved in a larger number of cases.

Natural Cross-fertilization.

During the year 1905 a collection of Indian tobaccos was made by the Púsa Farm, and the sowings were made the same year. A few plants of each sowing were allowed to run to seed without being bagged, and this seed was again sown in the autumn of 1906. In 1907, we selected seed from all the different plants that could be found in these sowings, and the seed from each plant was sown separately by us the same year. Opportunities for natural cross-fertilization at Púsa were therefore possible for two seasons, 1906 and 1907, before we took over the work. As only a few of the plants, however, were allowed to flower in both years, these opportunities were not numerous. Cross-fertilization, although previously possible in the various tracts of India from which the seed was collected, is not likely to be of frequent occurrence on account of the fact that but few plants are allowed to run to seed by the ryots and that the fields of *N. rustica* are very scattered. In 1908, it was found that out of 45 rows of *N. rustica* each grown from the seed of one plant, 9 were not uniform but contained plants differing from the rest. In 1908, a large number of these aberrant plants were bagged as well as the parent seed plants selected from the uniform rows. The seeds of these plants were again sown separately the same year. In every case the aberrant plants proved to be crosses and gave rise to the most diverse forms (Plate V). In one case infertile plants, with peculiar foliage which may possibly be hybrids between *N. rustica* and *N. tabacum* were observed (Plate VI). The selected plants from the uniform rows however bred true. Natural crossing is therefore frequent in many types of this species, and it will always be necessary in experimental work to obtain seed under bag.

In the Indian types of *N. tabacum* which have been studied up to the present the anthers in the majority of cases burst just as the bud unfolds. In some cases, however, pollination may take

place in the closed bud and in a few cases the anthers burst later when the corolla is half expanded.

The relative positions of the anthers and stigma and consequently the likelihood of self-pollination varies in the different types. The anthers may be below the stigma when they burst and may remain always at a lower level than the stigma making cross-pollination very probable, but this condition is rare. The most usual arrangement is that in which the ripe anthers surround or are just above the stigma when the flower opens. In these cases both cross and self-pollination are possible. In the fully open flowers the burst anthers and stigma may maintain this relative position or the anthers may be as much as 5 mm. above the stigma. In some cases the ripe anthers are well above the stigma in the fully open flower. In one or two types cases were found in which the ripe anthers surrounded the stigma but the latter was well above the empty anthers later.

Another difference was observed in the position of the stigma and anthers with regard to the orifice of the corolla. In some cases the anthers and stigma project into the air far beyond the corolla opening. In other cases the anthers and stigma remain low down in the tube of the corolla. In the majority of the types the anthers are either level with the corolla orifice or project slightly.

The arrangements for pollination in the various Indian types differ somewhat. The majority of the types readily set seed under bag but a few set only it self-pollinated.

Most observers agree that natural cross-fertilization occurs in this species but the extent to which it takes place when the types are grown next to next does not appear to be realised fully. The collection of Indian tobaccos made at Púsa in 1905 was grown for two years on the Púsa farm and a few plants of each kind were allowed to flower freely in 1906 and again in 1907. In 1907, we selected all the different types in this collection, and saved the seed from each plant separately. The various sowings were made by us in the Botanical area at Púsa the same year, and since that time all seed used to propagate the types has been raised under bag. Oppor-

AN EXAMPLE OF NATURAL CROSS-FERTILIZATION IN N. RUSTICA.

A SECOND EXAMPLE OF NATURAL CROSS-FERTILIZATION
IN N. RUSTICA.

tunities for natural crossing were therefore possible at Púsa for two seasons only, and these opportunities were limited by the fact that but few plants of each kind were allowed to flower and the period of flowering of the various kinds did not in all cases overlap. In 1908, observations were made on the uniformity of the cultures raised from one parent plant and any individuals which varied from the rest in the slightest degree were noted. In every case these aberrant plants were selfed and grown the next year when they gave rise to a large number of forms, often very diverse in habit and in leaves and which were obviously the products of natural cross-fertilization. In over a hundred cultures of this species in 1908, about 20 per cent. of the rows contained aberrant plants, thus showing to what a great extent natural crossing is possible when the various kinds are grown in close proximity and allowed to flower freely. Some of the aberrant plants only differed very slightly from the rest of the culture and much care was necessary to distinguish them. Sometimes they appeared only a little more robust than the rest, but in the case of every plant which showed the slightest variation in 1908, its progeny after bagging gave rise to uneven cultures made up of many different types.

Too much emphasis cannot be laid on the difficulty of observing the first generation of a cross between two varieties of tobacco in the field. The differences between many tobacco types are exceedingly small and can only be detected with precision after considerable study in places where such types are grown side by side and allowed to flower. Crosses between types unless they are very different would not be easy to observe in the F_1 generation even in cultures from single plants. In the field, where the great majority of the plants are topped, these differences would, in all probability, be overlooked. In the second and succeeding generations, when splitting takes place, the various types resulting from crossing could for the first time be observed.

In great contrast to the variable character of the progeny of a selfed aberrant plant is the great uniformity of the produce raised from the seed of an ordinary plant raised under bag.

From the practical point of view the significance of natural cross-fertilization in tobacco is very great. We have found at Púsa that natural crossing is the only cause of the breaking up of the type of any desirable kind of tobacco. If crossing is prevented and the type is raised from self-fertilized seed, the uniformity of the crop is extraordinary and no variability as regards the leaves or in time of ripening occurs. Uniformity in the shape, size and texture of the leaves and in the time of ripening is of the greatest importance in tobacco cultivation. Unless the crop ripens off uniformly, the difficulties and expense of harvesting and curing are increased. A crop made up of several types of plant differing in the size, shape, venation, texture and thickness of the leaves does not give a uniform product and unnecessary expense is involved in sorting out the various grades for market. The production and maintenance of the uniformity of the leaf is therefore a matter of the first importance, and is, moreover, the first condition for the improvement of the tobacco crop in India. This improvement can only be maintained by the prevention of natural crossing and by raising all seed under bag. Where a large number of varieties are grown at an experimental farm, the greatest care will have to be taken to keep the types pure and to prevent intercrossing.

The introduction of exotic tobaccos into India and also the testing of those from other localities in India itself are matters intimately associated with natural crossing. It usually happens that introduced seed is impure, giving rise to many types which in some cases resemble each other sufficiently to appear to be homogeneous. No useful purpose is gained by distributing such seed to cultivators. All the various types must first be sorted out, the seed in each case being raised under bag. In this way all crossed plants in the mixture can be eliminated and the best type or types isolated and pure seed distributed. If introduced seed is given to cultivators or used for experiments, it is not improbable that one or more natural crosses or stray plants might be selected as seed parents. In this way the type would be propagated from one or more undesirable plants, and the quality of the kind quickly lost.

2. Patwa. (Hibiscus Cannabinus, L.)

A large number of cultures of the fibre-yielding plant known locally as *patwa* (*Hibiscus cannabinus*) have been grown in the Botanical area at Púsa during the last four years, and some attention has been paid both to the method of pollination and the occurrence of natural crossing.

The flowers of this species open in the early morning before daybreak and begin to close about midday. The closing of the flower is fairly rapid and before sunset the partially withered corollas are twisted up in the manner shown in Plate VII. During the night still further twisting of the corolla takes place, giving rise to the cottage loaf shape of the withered flower shown opposite.

The method of pollination of the flowers of this species is of considerable interest and does not seem to have been studied in detail previously. When the flowers open, the stigmas are at the mouth of the staminal column and the anthers have not yet commenced to burst. Soon after daybreak, the anthers burst and are covered by the large echinulate pollen, the stigmas still remaining flush with the opening of the column. After this the turgidity of the filaments falls off and the burst anthers bend back towards the column. Simultaneously the styles elongate and carry the stigmas into the air beyond the opening of the column, and at this stage pollen grains are rarely seen on the stigmas. Sometimes, however, the styles bend outwards and carry the stigmas on to the pollen, thus bringing about self-pollination. Frequently no pollen is seen on the stigmas when the flowers begin to close about midday. If closed flowers are, however, carefully opened, it is found they are always well pollinated. Self-pollination is effected almost entirely by the closing of the corolla. The limb of the petal is thin, the claw very thick. The corolla closes by the falling towards the centre and twisting of the thin limbs. This brings the corolla in contact with the burst anthers and the completion of the closing of the flowers covers the stigmas with pollen. (Plate VII.)

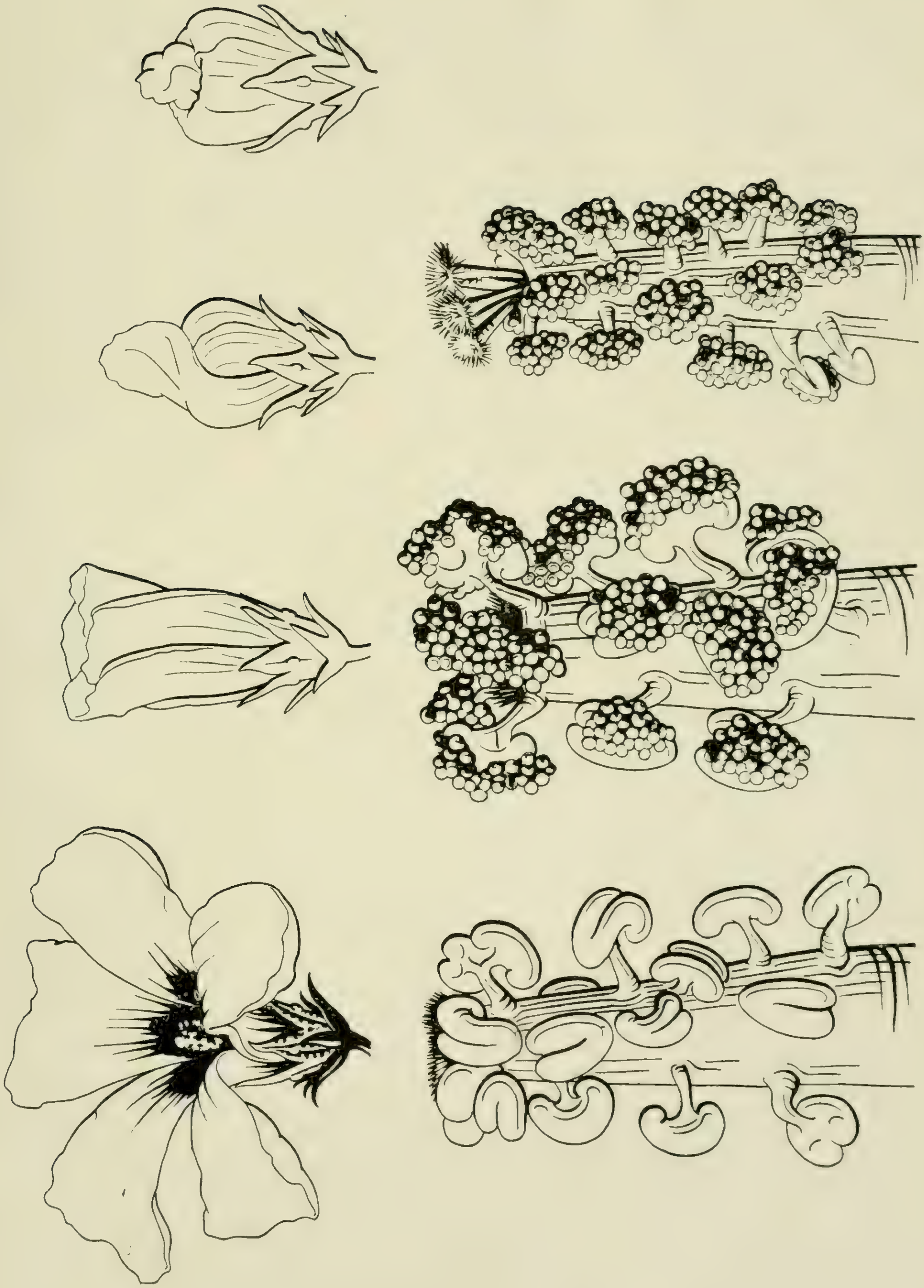
It will be seen that the flowers are adapted both for cross and self-pollination. From the time the styles begin to carry the stigmas beyond the opening of the column to the closing of the flower crossing is possible. Self-pollination, however, may occur during this period. A sufficient supply of seed is ensured by the very effective method of selfing when the flower closes.

The flowers of this species do not set seed under bag in the ord'nary way unless artificially self-pollinated. This is due to the fact that the flower closing mechanism does not act in the bag. The thin limbs of the corolla do not fall together and twist in the normal manner possibly on account of the even humidity of the air both outside and within the closing corolla.

Cross-fertilization is fairly common in this species when the various types are grown next to next and allowed to flower freely. Aberrant plants were found in nearly all the plots raised from the seed of free flowering plants in 1909. These were sown separate early in 1910. In all cases they split up into forms with entire and divided leaves and with variously coloured red and green stems.

3. Roselle. (Hibiscus Sabdariffa, L.)

Natural cross-fertilization does not appear to be equally common in all the cultivated species of the genus *Hibiscus*. Several varieties of Roselle, *Hibiscus sabdariffa*, have been grown next to next at Púsa for four years and not a single instance of natural crossing has been observed even at the edges of the plots where the plants of the varieties touch. Year after year the varieties come true and no crossing has been noticed. The flowers apparently always self-fertilize themselves. The flowers of this species open late in the morning and close at midday remaining open for not more than three hours. The stigmas are throughout flush with the opening of the column and do not grow into the air as in the case of *Hibiscus cannabinus*. The filaments are very short and the anthers burst round the opening of the column. Self-pollination is favoured by these arrangements and the completion of the process is brought about by the closing of the flower. (Plate VIII.)



THE POLLINATION MECHANISM OF HIBISCUS CANNABINUS.

PLATE VIII.

THE POLLINATION MECHANISM OF HIBISCUS SABDARIFFA.

4. Cotton.

Little attention has been paid to cotton from the Botanical point of view by the writers at Púsa as this crop does not thrive in North Bihár. In 1907, a collection of Indian cottons, sent by Professor Gammie from Poona, was sown in the Botanical area at Púsa. These cultures were by no means uniform and appeared to contain several natural crosses. The seed of one of these aberrant plants found in one of the cultures of *Gossypium arboreum*, L., was sown separately in 1908 by Mr. G. P. Hector and gave rise to very variable offspring, clearly proving that the parent plant was of hybrid origin.

The first and most extensive observations on this subject in India have been made by Leake[1] at Cawnpore who sums up his results as follows: "It is as yet impossible to state with certainty to what extent cross-fertilization takes place. The evidence so far obtained indicates that natural crossing occurs with sufficient frequency to render it impossible to keep types pure when they are grown in the proximity of other types." Subsequently Dobbs[2] at Lyallpur independently made some interesting observations on this subject which are best given in the author's own words. He states: "By separate sowing on the farm of seed from single known parents evidence has been obtained, conclusive to anyone familiar with the common reactions caused by hybridization, that a very large proportion of the cottons on the farm, particularly those that are most vigorous, are crosses between distinct varieties within each of the above main types, *e.g.*, seedlings grown from a supposed 'Khaki' American parent having a light brown lint gave 'Khaki,' light brown and pure white lint in approximately Mendelian proportions. Again 'Dharwar' cotton consists, on the farm, of innumerable varieties, early and late, productive and unproductive, of which half do not breed true to type, and it may be inferred that this variation has arisen by hybridization. In

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[1] Leake, *Journal and Proceedings of the Asiatic Society of Bengal* (*New Series*), Vol. IV, No. 1, 1908, p. 19.

[2] Dobbs, *Annual Report of the Lyallpur Agricultural Station for* 1907-08, Lahore, 1908.

this lie great possibilities of improvement by mere systematic selection as well as the explanation of the extraordinary deterioration noted below of Egyptian cotton grown from unselected seed. It is in fact clear that where a valuable variety grows in close proximity to a worthless one of the same main type, great care, in the following year, in the selection of parents for seed production, is necessary if the valuable strain is to be kept pure. This, agreeing with experience in America where (pp. 131 and 132 of the *Yearbook of the U. S. A. Agricultural Department*, 1903) it is advised that seed fields of valuable cotton should be located 'half a mile or more from any other cotton,' should be taken into account in seed-growing in the future."

Natural crossing in cotton has been observed in other countries. In Egypt, Balls[1] considers that the amount of cross-fertilization which takes place in the Egyptian cotton fields is between five and fifteen per cent. per annum and the accumulated effect of this annual crossing maintains the crop as a mass of natural hybrids. It is not surprising therefore that the introduction of Egyptian cotton seed into Texas has given rise to difficulties which can be entirely explained by the occurrence of natural crossing both previous to and subsequent to the introduction of this crop into America. The American experience, which is no doubt typical, is summed up by Cook[2] in several papers which are of great interest to workers on cotton in India.

5. Linseed.

The information on the subject of the modes of pollination of the cultivated forms of linseed (*Linum usitatissimum*, L.), has been summed up recently by Fruwirth,[3] who states that as a general rule self-pollination is the rule and that good setting is obtained under bag without loss of vigour. While he does not appear to

1 Balls, *Journal of Agricultural Science*, Vol. II, 1908, p. 378.

2 Cook, *Bulletins* 156 & 157, *Bureau of Plant Industry, U. S. Department of Agriculture*, 1909.

3 Fruwirth, *Die Zuchtung der landw. Kulturflanzen*, Bd. III, 1906, s. 45,

have observed any cases of natural crossing, nevertheless it is pointed out that this is not impossible.

During the last three years a large number of single plant cultures of both European and ordinary Indian linseed have been grown by us next to next in the Botanical area at Púsa. The introduced kinds are those commonly grown for fibre in Europe and are generally characterised by tall, thin, unbranched stems bearing comparatively few capsules. The Indian linseeds are very different in general appearance. They are short much branched forms with thick stems and many capsules.

In 1910 many of these single plant cultures contained tall and short, late and early, many and few seeded plants and in some cases the colour of the flowers of the plants in each culture were markedly different.

Recently attempts have been made in India to introduce the cultivation of linseed for fibre purposes, and for this purpose several consignments of European seed have been grown on the Púsa Farm and at one of the indigo factories in Bihár. It is obviously important to maintain the best fibre-yielding types of linseed uniform. Besides accidental admixture with country linseed the possibility of crossing between the tall fibre-yielding types and the dwarf branched country kinds has to be considered. If this takes place, the uniformity of the type and its value for fibre will quickly be lost.

After three years cultures of single plants of the fibre-yielding linseeds at Púsa we have no doubt that natural crossing takes place under Indian conditions, and that this fact will have to be taken into serious consideration in the growth and distribution of linseed for fibre purposes.

6. The Cruciferous Oil Seeds.

Several species of oil-yielding seeds belonging to the *Cruciferæ* are widely cultivated in India and the seed is an important article of commerce. The oil seeds of Bihár and Bengal belonging to the genus *Brassica* have been studied by Prain,[1] who grew for

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[1] Prain, *Agricultural Ledger*, No. 1, 1898.

one year a collection of seed from the various Districts of the Province at Sibpur. He concludes his paper as follows :—

"As regards the relationship that our three mustard oil crops bear to the corresponding crops in Europe, it may be tentatively held :

(1) That *rai* (*Brassica juncea*) is a crop not grown in Europe, at any rate on a commercial scale, but that it takes the place here of *B. nigra* and *B. alba*, which in turn are not grown in India ;

(2) That *sarson* (*B. Campestris* var. *sarson*) is a crop not grown largely if at all in Europe, but that in India it takes the place of both *B. Campestris*, var. *oleifera*, and *B. rapa*, var. *oleifera*, which in turn are hardly ever met with here, finally;

(3) That *tori* (*B. napus*, var. *dichotoma*) seems to be the same plant as *B. precox* (summer-rape), or if not the same at least very like and very near it, and is undoubtedly the plant that in India takes the place of *B. precox* and of *B. napus* var. *oleifera*."

In the genus *Brassica* according to Knuth,[1] the various species are adapted for cross rather than for self-pollination. Detailed observations on the fertilization of the species cultivated in India do not seem to have been made up to the present.

Indian Mustard or Rai.

A large number of single plant cultures of *rai* have been sown at Púsa. The study of the various forms found in this crop in India is not yet complete nor is the study of the flowers. It is hoped to publish later a detailed account of the botany of the Indian oil seed crops.

Rai readily sets seed under bag and from a consideration of the single plant cultures already studied at Púsa it appears that a good deal of self-pollination naturally takes place.

In 1909, 82 single plants of *rai* were sown at Púsa. Of these 55 bred true and 27 split. Seventeen plants split with regard to the close or open arrangement of the pods (Fig. 3, Plate IX), while 10 split into tall and short plants.

[1] Knuth, l. c.

Indian Colza or Sarson.

Prain states that there are two races of *sarson* in Bengal—one with erect pods and one with pendent pods. *Sarson* readily sets seed under bag and a certain amount of self-fertilization is therefore to be expected in free-flowering plants.

Forty-eight single plants of white seeded sarson were sown in 1909. The splitting which took place was in two directions, (*a*) as regards the colour of the seeds, red or white, and (*b*) as regards the erect or pendent nature of the pods.

Forty-five out of the 48 plants bred true as regards seed colour, the remaining three giving rise to red and white seeded plants as follows :—

No.	Parent plant, 1909.	Progeny, 1910.	
		Plants with white seed.	Plants with red seed.
1	Seed, white ..	19	2
2	,, ,, ..	23	1
3	,, ,, ..	10	1

The red seeded plants are probably natural crosses in the F_1 generation. These will be sown separately this year and the progeny examined.

Out of eleven plants with pendent pods sown seven bred true and four split as follows (Fig. 2, Plate IX) :—

No.	Parent Plant 1909.	Progeny, 1910.	
		Plants with erect pods.	Plants with pendent pods.
1	Pods pendent ..	1	17
2	,, ,, ..	7	5 (slightly pendent).
3	,, ,, ..	1	13
4	,, slightly pendent ..	8	4

Thirty-seven plants with erect pods were sown and of these 28 bred true, while 9 split into erect and slightly pendent pods as follows :—

No.	Parent plant, 1909.	Progeny, 1910.	
		Plants with slightly pendent pods.	Plants with erect pods.
1	Pods erect	6	18
2	,, ,, ...	8	13
3	,, ,, ...	5	11
4	,, ,, ...	4	13
5	,, ,, ...	9	3
6	,, ,, ...	1	10
7	,, ,, ...	1	23
8	,, ,, ...	2	12
9	,, ,, ...	3	15

In the group of red seeded *sarson* 13 single plants were sown in 1909, six of which split according to seed colour as follows. The rest bred true. In addition to the splitting as regards seed colour most of the cultures varied in the size and arrangement of the pods. (Fig. 1, Plate IX.)

No.	Parent plant, 1909.	Progeny, 1910.	
		Plants with white seed.	Plants with red seed.
1	Seed red	5	15
2	,, ...	7	9
3	,, ...	2	24
4	,, ...	4	24
5	,, ...	4	7
6	,, ...	7	11

Tori or Indian Rape.

The types of *tori* ripen early and considerably in advance of *rai* and *sarson*. Setting under bag is not so easy as in *rai* and *sarson*, and further work is in progress on the method of pollination in this species.

Only two cases of splitting as regards seed colour and habit were met with in 27 single plant cultures made in 1909. One plant gave rise to 3 white seeded plants and 14 red seeded plants. One parent plant with spreading habit gave 3 erect and 12 spreading plants.

PLATE IX.

NATURAL CROSSING IN RED AND WHITE SEEDED SARSON AND IN RAI.

1. Red seeded Sarson. 2. White seeded Sarson. 3. Rai.

Taramira (Eruca Sativa, Lam.)

Eruca sativa is extensively cultivated in India as a *rabi* oil seed. Knuth[1] states with regard to this plant: "The flowers are homogamous. The anthers dehisce introsely and are placed so close to the stigma that automatic self-pollination is inevitable." We venture to doubt the correctness of these statements as applied to *taramira* in India. In spite of a large number of trials on well-grown plants at Púsa practically no setting has been obtained under bag. Free-flowering plants, however, set seed freely.

Nine single plant cultures were sown in 1909. In 1910 practically no two plants were alike in any culture. Crossing seems to have taken place in this species in India to an extraordinary extent and the crop seems to be a mass of hybrids in which self-pollination appears to be very rare.

7. Opium Poppy.

Several types of opium poppy (*Papaver somniferum*, L.) are grown in India. In Bihár white flowered types occur, while in Central India purple flowered kinds are cultivated. Forms with entire and more or less divided petals occur, and there are differences in the shape and size of the capsule, in the shape of the leaves and in the hairiness of the stems.

Fruwirth[2] gives a detailed account of the modes of pollination in this species and sums up his own experiments on the subject as well as those of previous observers. The flowers are said to be adapted both for self and cross-pollination, the receptive stigmas being partly self-pollinated before the flower opens. Cross-pollination is effected by insects which visit the flowers to collect pollen. Most observers agree that seed is set under bag, but to a less extent than when the flowers are selfed and still less than when they are allowed to flower freely. This has been our general experience at Púsa with the Indian forms. Fruwirth states that pollinating from different flowers on the same plant or from different plants of the same kind gave as certain setting as free-flowering. The

[1] Knuth, l. c.

[2] Fruwirth, *Die Zuchtung*, Bd. II, 1909, s. 178.

capsules in the first case contained more seed than those produced by selfing, while those in the second case were much better. Selfed seed gave fewer plants than free-flowering seed. No loss of vigour from continual selfing seems to have been noticed by this investigator. Forms which stood next to one another and were allowed to flower freely always crossed. Our observations at Púsa in 1909 amply bear out Fruwirth's work on the frequent occurrence of natural crossing in the opium of India.

In 1909, 127 single plants of opium of many different types were sown singly and the progeny in 1910 was examined and gave rise to mixed offspring, only 9 plants breeding true. Splitting took place in many directions, for example, into divided and nearly entire leaves, round or oblong capsules, hairy and smooth stems, in colour of the margin and eye of the petals and in the amount of division of the petals.

As regards the amount of division of the leaves two good cases of splitting were observed :—

No.	Parent plant, 1909.	Progeny, 1910.	
		Deeply divided.	Slightly divided
4/136	Leaves slightly divided	14	43
4/134	,, ,, ...	29	61

Usually smooth stemmed plants bred true. Almost all the hairy stemmed plants gave smooth and variously hairy plants.

A great deal of splitting was observed as regards the colour of the petals (Plates X & XI). Out of 35 single plants with white petals with an entire margin, 14 bred true and 21 split. Splitting took place both with regard to colour and to the character of the margin whether entire or divided. As a rule the flowers with entire white petals which split gave white and light red petals. Plants with divided petals generally bred true but colour differences often came in. Thus out of 12 plants with white divided petals in 1909 only three bred true in every respect, but, as regards divided petals only, 10 came true.

THE PROGENY OF A PLANT OF OPIUM POPPY WITH VIOLET DIVIDED PETALS.

THE PROGENY OF A PLANT OF OPIUM POPPY WITH ENTIRE RED PETALS.

Enough has been said to show that it is impossible to grow a collection of Indian poppies side by side for experimental purposes and to allow them to flower freely. In a single season the various cultures would be contaminated to such an extent by vicinism that further work would lead to no result. A collection of poppy seeds from the various districts of India was sown at Púsa in 1908 and 1909 showed that except in the case of seed from the United Provinces each set of seed gave rise to mixed plots and it appeared probable that crossing goes on to a great extent in the cultivators' fields themselves and that the present opium crop is often largely composed of hybrids.

8. Safflower.

Safflower (*Carthamus tinctorius*, L.) is widely cultivated in India both for the dye in its flowers and for the oil in the seeds. Even a casual examination of the crop as grown by the cultivators shows that a very large number of forms are to be seen in the same field.

Some setting is obtained under bag. Out of 800 heads bagged in 1909 only 181 produced seeds and the number of seeds in each case was far below that obtained in free-flowering heads.

In 1910 the amount of setting obtained under bag was carefully determined in the case of eight plants. The results are given in the following table :—

No.	No. of heads bagged.	No. of heads which formed seed.	No. of seeds formed.	No. of seeds in unbagged heads.
1	10	3	32	356
2	13	8	63	489
3	12	11	131	402
4	10	6	54	404
5	9	8	169	323
6	11	8	99	697
7	10	6	53	516
8	10	7	139	488
Total	85	57	740	3,669

It will be seen that only 67 per cent. of the heads formed seed, while the total amount of seed was only 20 per cent. of what would have set if the heads had not been bagged.

Seventy-six single plants raised from one sample of local seed were sown in 1909 and out of these only two have bred true in all respects. In this crop, therefore, we have to deal with a plant which normally crosses and the point to determine is not how much crossing, but how frequently self-pollination takes place.

Splitting took place in many directions, namely, in the colour of the flowers, in the habit of the plants, whether tall or spreading, in the felting or smoothness of the heads, and in the character of the leaves and bracts. (Plate XII.)

The colour of the flowers may be yellow, or various shades of orange turning into red when the flowers wither. Yellow flowers when fading give a dirty yellow colour. As an example of splitting in flower colour the progeny of two yellow and 2 orange flowered plants selected in 1908 may be given. (Plate XIII.)

No.	Parent plant, 1909.	Progeny, 1910.
1	Orange flowers ...	Yellow flowers (2). Light orange flowers (1). Orange flowers (2).
2	" " ...	Yellow flowers (1). Light orange flowers (1). Orange flowers (1).
3	Yellow flowers ...	All yellow flowers.
4	" " ...	Yellow flowers (2). Light orange (1). Orange flowers (1).

Nine other plants split into orange and light orange flowered plants.

As regards the felting of the buds nine cases of splitting occurred and 12 good examples of splitting according to the erect or spreading habit were noted. Splitting also took place according to the character of the leaves (spiny or spineless), bracts and as regards time of maturity (early and late). Taking into consideration all these points only two cultures bred true.

THE PROGENY OF A SINGLE PLANT OF SAFFLOWER.

PLATE XIII.

THE PROGENY OF A SELF-POLLINATED PLANT OF SAFFLOWER
WITH ORANGE FLOWERS.

IV. MONOECIOUS AND DIOECIOUS CROPS.

Maize, as is well known, is largely cross-fertilized. Many breeders at the present time are agreed that not only is continuous self-pollination injurious to the crop but that the best chances of improvement lie in breeding on a broad basis and in permitting natural crossing to take place within limits. The uniformity which is possible in narrow breeding is likely to be of less importance than the vigour and consequent increased yield which results from crossing within broad limits. Yield is likely to be of greater importance than uniformity.[1,2]

Our observations on crops of this group are limited to castor (*Ricinus communis*, L.). In 1908, ten single plant castor cultures were made from plots grown at Púsa the previous year from various samples of local Bihár seed and from two samples of castor from Africa. In all cases the cultures showed that natural crossing had taken place, a result which was fully expected. Any attempt to introduce into India an exotic variety of this crop, however excellent, could have little effect as its qualities would quickly be lost through crossing with the indigenous crop.

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[1] Collins, *Bull. 141, Bureau of Plant Industry, U. S. Dept. of Agr.*, 1909.

[2] Shull, *The Composition of a field of Maize*, American Breeders' Association, vol. 4.

V. THE BEARING OF NATURAL CROSS-FERTILIZATION ON THE IMPROVEMENT OF INDIAN CROPS.

The extent to which natural cross-fertilization occurs in India is of great importance to and is closely bound up with the improvement of the crops of the country. The extent to which natural crossing takes place largely determines the methods which can be adopted in improving a crop, it influences the introduction of exotics, the testing of varieties and the distribution of seed to cultivators. In taking up any crop therefore the first condition for successful work is a study of the method of pollination and the extent to which natural crossing takes place. Based on accurate information on these matters the application of correct methods of improvement is almost bound to lead to success. It is proposed to discuss briefly the precise bearing of the facts brought forward in the present paper on the choice of the methods of improvement, on the introduction of exotics, on the testing of varieties and also on seed distribution.

The significance of natural crossing from the systematic standpoint must not be forgotten. It is obvious that great care must be exercised in assigning a varietal position to any aberrant forms met with unless they have been shown to breed true from seed. In many cases where natural crossing occurs, these forms are likely to be mere Mendelian combinations of the characters of two existing species or varieties which in the next generations would give rise to a large series of forms.[1]

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[1] Since this paper was written some interesting observations on this subject have been made in England by Henry (*Gardeners' Chronicle*, Apr. 23 and 30, 1910). This investigator has shown that many aberrant forms of forest trees which were formerly regarded as varieties or even as distinct species are nothing more than first crosses.

1. The methods of Improving Crops.

Cook[1] in a recent paper has discussed the broad lines of plant improvement. He distinguishes three main methods which are described as follows :—

"*Broad breeding* is the condition of descent found in natural species, which consist of millions of diverse individuals freely interbreeding with each other so that the vast number of lines of descent of the species are joined into a broad network.

Narrow breeding is the condition of descent found in carefully selected varieties, consisting of relatively small numbers of closely similar individuals interbreeding with each other to form a narrow network of descent.

Line breeding is the condition of descent found in strains descended from single individuals propagated without interbreeding with other lines of descent so that no network is formed." Cook regards vegetative propagation, parthenogenesis, self-fertilization and in-and-in breeding as forms of line breeding.

Line breeding or growth from single plants is the method applicable to crops which are usually self-pollinated such as the cereals and pulses or to crops like tobacco where uniformity is the first consideration and where crossing is easily prevented and a large supply of self-pollinated seed is a simple matter. If natural crossing occurs however to an appreciable extent, as, for example, in wheat at Lyallpur, occasional continued selection in the pure line cultures will be necessary in addition to roguing. In this way the purity of the types can be ensured and the effects of crossing eliminated.

Broad breeding is the method essentially applicable to crops like maize where yield and vigour are more important than uniformity.

In crops like cotton, and the *Brassica* oil seeds, where a certain amount of crossing takes place, the choice seems to lie between broad and narrow breeding. Propagation in pure lines, besides

[1] Cook, *Bull. 146, Bureau of Plant Industry, U. S. Dept. of Agr.*, 1909.

its difficulty, might lead to loss of vigour and it may well be an advantage to sacrifice absolute uniformity to yield. How far a crop in which, say, from 5 to 10 per cent. of natural crossing takes place, can be propagated successfully without loss of vigour from a single fixed plant obtained either by selection or as the result of hybridization is a matter which, at the present time, calls for long-continued and accurate experiment. Can the method of single plant selection be applied to crops like the *Brassica* oil seeds or to cotton and natural crossing be avoided without loss of vigour ? If so, the study of pure lines can be applied to such crops. The whole matter turns on the possible ill-effects of in-and-in breeding in such crops and on the practical difficulties in the prevention of vicinism.

The extent to which natural crossing takes place obviously affects the production of new varieties by hybridization and the study of the inheritance of characters. Even when spontaneous crossing is rare its possible effects on the various hybrid generations must be expected. In crops where crossing frequently takes place the difficulties are greatly increased if accurate and trustworthy results are to be obtained. Some years must necessarily elapse before pure line cultures can be obtained and the splitting forms eliminated. After the crosses have been made all subsequent work will have to be done with bagged plants so as to exclude the effect of natural crossing.

2. The Introduction of Exotics.

Natural crossing has obviously an important bearing on the introduction of exotics. If crossing takes place in a crop, it is likely that any consignment of seed from another country will not be uniform but will contain hybrids. The seed must first be grown, if possible apart from similar local crops, and the constitution of the crop determined. Methods of selection may in consequence have to be applied, and some years may elapse before any of the seed can be distributed to cultivators. The recent failure of the introduction of Egyptian cotton into Texas[1] appears to have

[1] Cook, *Bull. 156, Bureau of Plant Industry, U. S. Dept. of Agr.*, 1909.

been due to the fact that it was not understood that the cotton crop in Egypt is a mass of hybrids some of which are exceedingly undesirable. Two difficulties therefore face the introducer of an exotic in which natural crossing occurs. The introduced crop is almost certain to contain splitting forms, some probably undesirable. Further the exotic will probably cross with the local crops.

The effects of natural crossing in the introduction of exotics are often erroneously attributed to the influence of acclimatisation. It is obvious that the effects of acclimatisation can only be studied in a crop in which natural crossing is altogether prevented.

3. The testing of varieties.

Varieties can only be safely collected and tested side by side at an Experiment Station if cross-fertilization either does not occur at all or to so small an extent that an occasional rogueing of the plots is sufficient to keep them pure or if, as in tobacco, it can be prevented altogether by artificial means. Variety trials of crops like maize and castor oil are difficult on account of the certainty of contamination by vicinism. Much useless work is continually being done in the trial of varieties which cross among themselves. The constitution of the crop and therefore the yields change from year to year and the results are erroneously attributed to the varying influence of the season.

4. The Distribution of Seed.

The final outcome of the improvement of any crop in India is naturally the growth for distribution to the cultivators of improved and tested seed. The investigator, not unnaturally, is anxious to begin this work at the earliest possible moment as it is regarded as a proof of the successful consummation of his efforts. In crops like wheat and tobacco there are no particular difficulties in the seed supply except in distributing wheat in the Canal Colonies of the Punjab where natural crossing is comparatively common. A large supply of self-fertilized tobacco seed is easily produced, and the scattered nature of the cultivation and the few plants kept for

seed will greatly limit crossing in the Districts. In other crops, however, where crossing is more frequent, the improved seed, even if kept pure on the seed farms, will soon lose its qualities through vicinism when grown by the people. Unless some co-operative arrangement can be devised and put into practice by which an improved variety entirely replaces the old in a locality, the good done by seed distribution in such crops can easily be exaggerated.

PUSA,
March 1910.

Note added.— While this paper was passing through the press a large number of single plant cultures of *til* (*Sesamum indicum*, L.) and of *niger* (*Guizotia abyssinica*, L.) have been grown at Pusa. In both these crops natural cross-fertilization has been found to occur to a considerable extent the details of which will be published in a subsequent paper.

PUSA,
Oct. 14th, 1910.

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